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Project Summary Report for Pilot-Scale Demonstration of Red Water Treatment by Wet Air Oxidation and Circulating Bed Combustion

October 1995
Contract No. DACA31-91-D-0074
Task Order No. 0005

Prepared by:

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Prepared for:

U.S. Army Environmental Center
Aberdeen Proving Ground, MD 21010-5401

FINAL

PROJECT SUMMARY REPORT

FOR

PILOT SCALE DEMONSTRATION OF RED WATER TREATMENT BY WET AIR OXIDATION AND CIRCULATING BED COMBUSTION

VOLUME 3 OF 4

USAEC Contract No. DACA 31-91-D-0074
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As part of the Army's ongoing research and development program related to red water (K047) treatment, the U.S. Army Environmental Center (USAEC) contracted IT Corporation to prepare conceptual designs and plans for pilot scale demonstrations of two treatment technologies: wet air oxidation (WAO) and circulating bed combustion (CBC). The project objectives included development of a Test Plan and a Health and Safety Plan for these demonstrations. The Project Summary Report presents the conceptual designs. This Project Summary Report and the Test Plan and Health and Safety Plan are intended to serve as guides for development of complete project plans when the technology demonstration program is implemented. Because red water is not currently available for testing and the test site (host facility) where the demonstrations will be conducted has not been identified, these documents are intended to be generic in nature.

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Preface

As part of the U.S. Army's ongoing program related to the research and development of red water treatment technologies, the U.S. Army Environmental Center (USAEC) contracted IT Corporation to prepare conceptual designs and plans for pilot-scale demonstrations of two treatment technologies: wet air oxidation (WAO) and circulating bed combustion (CBC). The project objectives also included development of a Test Plan and Health and Safety Plan for these demonstrations, and preparation of a Project Report. This Project Report is intended to summarize the conceptual designs, Test Plan, and Health and Safety Plan and to serve as a guide for activities when the next phase of this program (i.e., conducting the demonstrations) is implemented.

Red water is not currently generated by the U.S. Army or any other part of the U.S. Department of Defense nor has it been generated in the recent past. An accurate and complete database does not exist in regard to the chemical and physical nature of red water. Due to this lack of waste characterization data, it was not possible to complete an accurate analysis of the associated testing and treatment requirements. Additionally, the source of red water for testing and the location where the tests will be conducted (i.e., the host facility) have not been identified. Therefore, waste- and site-specific concerns and requirements cannot be accurately or completely addressed at this time. As a result, this phase of the investigation included completion of plans and conceptual designs. Completion of system designs and finalization of test and safety plans must be completed in the future prior to initiation of the demonstration program.

This Project Report outlines the current project status and identifies the steps which must be completed prior to conducting the demonstrations. These include: selecting a host facility, obtaining red water for the demonstrations, characterizing the red water, preparing final process and equipment designs, finalizing Health and Safety and Test Plans, and acquiring the test equipment. Because of the unique and largely undocumented nature of red water, once a source has been identified, a critical initial objective will be characterization of the physical and chemical nature of the waste and a review of the associated treatment requirements.

Table of Contents

Appendix A is in Volume 1; Appendix B is in Volume 2; Appendix C is in Volume 3; and Appendices D, E, and F are in Volume 4.

List of Figures

CONCEPTUAL DESIGN AND RELATED DOCUMENTS

RED WATER INCINERATION PILOT PLANT (CIRCULATING BED COMBUSTION SYSTEM)

Prepared for:

U.S. Army Environmental Center (USAEC)
Aberdeen Proving Ground, Maryland

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U.S. Army Environmental Center
Red Water Treatment Technology
Test Plan and Site Preparation
Aberdeen Proving Ground, Maryland

CONCEPTUAL DESIGN AND RELATED DOCUMENTS

Tab Index

List of Tables

CONCEPTUAL DESIGN AND RELATED DOCUMENTS

List of Drawings

List of Acronyms

acfm	actual cubic feet per minute
ACGIH	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
APCS	air pollution control system
AWFCO	automatic waste feed cutoff
Btu/lb	British thermal units per pound
CBC	circulating bed combustors
CCS	central control system
CEM	continuous emissions monitoring
CFR	Code of Federal Regulations
CGV	combustion gas velocity
Cl_2	chlorine
dBa	decibel
DHHS	Department of Health and Human Services
DP	differential pressure
DRE	destruction/removal efficiency
EPA	U.S. Environmental Protection Agency
feet/sec	feet per second
gpm	gallons per minute
gr/dscf	grains per dry standard cubic feet
HASP	health and safety plan
HAZOP	hazardous and operability study
HCl	hydrochloric acid
hp	horsepower
H&S	health and safety
I.D.	induced draft
in. w.c.	inches water column

List of Acronyms *(Continued)*

IT	IT Corporation
lb/hr	pounds per hour
M&EB	mass and energy balance
MM5	Modified Method 5 (sampling train)
MMT	multi-metals train
mph	miles per hour
MSDS	Material Safety Data Sheet
MSHA	Mine Safety and Health Administration
ng/L	nanogram per liter
NIOSH	National Institute of Occupation Safety and Health
OSHA	Occupational Safety and Health Administration
PFD	process flow diagram
PIC	product of incomplete combustion
P&ID	piping and instrumentation diagram
PLC	Programmable Logic Controller
POHC	principal organic hazardous constituent
PPE	personal protective equipment
ppm	parts per million
ppmdv	parts per million dry volume
PSD	particle size distribution
P&ID	piping and instrumentation diagrams
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RAAP	Radford Army Ammunition Plant
RATA	relative accuracy test audit
RCRA	Resource Conservation and Recovery Act
SOP	standard operating procedure
THC	total hydrocarbons

List of Acronyms *(Continued)*

TLV	Threshold Limit Value
TNT	trinitrotoluene
TWA	time-weighted average
UPS	uninterrupted power supply
USAEC	U.S. Army Environmental Center
VOST	volatile organic sampling train
WAO	wet air oxidation

1.0 INTRODUCTION

1.0 Introduction

The red water incineration conceptual design project was awarded to IT Corporation (IT) by the U.S. Army Environmental Center (USAEC), located in Aberdeen Proving Ground, Maryland. This project was awarded to IT's Cincinnati office and the design documents were prepared by IT's Knoxville office.

Red water is the aqueous effluent generated during sellite purification of crude trinitrotoluene (TNT). Red water is a reactive hazardous waste, U.S. Environmental Protection Agency (EPA) Hazardous Waste number K047. In a previous project, 30 technologies were evaluated for their effectiveness in treating red water. That project determined that wet air oxidation (WAO) and circulating bed combustors (CBC) merited further study. This document presents the conceptual design and the layout of a pilot CBC, along with a test plan and a safety plan.

This CBC conceptual design is prepared as part of a task entitled "Red Water Treatment Technology Test Plan and Site Preparation" for the USAEC. The objectives of the task are to prepare test and safety plans, determine the best conceptual designs, and prepare layouts for pilot-scale CBC and WAO treatment systems. Because of the uncertainty of the pilot-scale demonstration location, the units are designed to be transportable. The conceptual design develops the CBC design to approximately the 10 percent stage; further process engineering and detailed design engineering are necessary prior to construction of the pilot-scale units.

The purposes of this document are to:

- Provide CBC process information in support of other project documents (e.g., Test Plan, Health and Safety Plan, and Project Report
- Provide a conceptual-level design and cost estimate for a pilot-scale CBC unit.
- Identify areas that should be investigated during subsequent design and pilot-scale testing activities.

As previously indicated, other documents prepared for this task include a Test Plan, Health and Safety Plan, and Project Report; these documents are provided under separate cover.

The pilot CBC presented herein is a transportable incineration system consisting of a combustion chamber, a hot cyclone, a loop-seal, a partial quench, a baghouse, an induced draft (I.D.) fan, and the stack. The CBC operating temperature of 1600°F is maintained by adding auxiliary fuel (natural gas) directly to the combustion chamber. The red water and the bed material are fed directly to the loop-seal. Ash and bed material are removed from the combustion chamber and cooled by the ash cooler conveyor. The design basis for the CBC, as directed by USAEC, is a thermal treatment capacity of 1.5 gallons per minute (gpm) of red water.

This document contains the following major chapters:

- ***1.0 Introduction*** - Brief introduction to the project and contents.
- ***2.0 Waste Profile*** - Presents a description of red water including the assumptions made about the waste profile during the design of the CBC.
- ***3.0 Waste Feed Chemistry and Selection of Circulating Media*** - Describes the chemical and physical considerations that were studied to determine the optimum circulating media.
- ***4.0 Block Flow Diagram*** - Presents the CBC block flow diagram.
- ***5.0 Conceptual Design Basis*** - Presents the conceptual design basis for the red water incineration pilot plant.
- ***6.0 Process Description*** - Presents an overview of the combustion system and a description of each key system component.
- ***7.0 PFDs and P&IDs Package*** - Presents the process flow diagrams (PFD) and the piping and instrumentation diagrams (P&ID) for the CBC.
- ***8.0 Equipment List*** - Presents a list of the key pieces of equipment.
- ***9.0 Equipment Specifications*** - Presents the specification sheets for each key CBC component.
- ***10.0 General Arrangement Drawings*** - Presents the general arrangement plan and the shipping arrangement for the CBC.

- ***11.0 Electrical One-Line Drawings*** - Presents the electrical one-line drawings for the CBC.

- ***12.0 Mass and Energy Balance Outputs*** - Presents the results of mass and energy balances conducted for the normal, start-up, and hot idle operating scenarios.

- ***13.0 Pilot Plant Cost Estimate*** - Presents the estimated cost for the CBC pilot plant.

- ***14.0 Recommended Tests and Analyses*** - Presents a list of the recommend tests and analyses to be conducted during the pilot test.

- ***15.0 Operations and Safety Considerations*** - Presents the CBC operations and safety considerations.

- ***16.0 Operations Manual*** - Presents a draft CBC operations manual.

- ***17.0 Performance Test Plan*** - Presents a draft performance test plan to test CBC's ability to meet regulatory and warranty performance requirements.

- ***18.0 Bench-Scale Testing*** - Presents the test plan and the results of a bench-scale CBC system testing for agglomeration tendencies while incinerating surrogate red water.

- ***19.0 HAZOP Analysis*** - A hazard and operability study was performed to assess potential failures in the circulating bed combustor and recommend additional safeguards to prevent or mitigate the consequences of these failures.

2.0 WASTE CHARACTERIZATION

2.0 Waste Characterization

Red water is the aqueous effluent generated during sellite purification of crude TNT. Red water has a deep red, or sometimes black color, and is a complex and somewhat variable mixture. Depending on the TNT production process and degree of water recycle used, red water generally contains 15 to 30 percent solids, has a pH of 7 to 9.7 and a specific gravity of 1.1. Roughly half of the solids are inorganic salts and the rest are nitrobodies. This information was gathered from a document titled "Review of Canadian industries limited's Boloeil facility as a candidate for a SRP pilot test" (RAAP, 1988).

The CBC pilot plant is designed to process a maximum of 1.5 gpm of red water containing 15 weight percent solids. The solids have a heat value of 3,200 British thermal units per pound (Btu/lb).

The red water can contain up to 30 percent of solids. Typically, the solid content in the red water is 15 percent, and therefore, a solid content of 15 percent was selected as the basis. Even if the solid content in the red water is 30 percent occasionally, there may be concern regarding agglomeration tendencies. The agglomeration of solids is primarily a function of temperature and not the concentration. The increase in solid content will impact the bed material feed rate and ash discharge rate. The associated equipment is designed to handle additional capacities, if required.

For waste characterization purposes, it is assumed that 45 percent of the solids are inorganic salts and the rest are nitrobodies (Table 2-1). The inorganic components are primarily sodium sulfites/sulfates and sodium nitrites. The nitrobodies are primarily sodium sulfonate of 2,4,5-TNT and TNT-sellite complex (Table 2-1). The information contained in Tables 2-1 and 2-2 are gathered from the reference cited in the first paragraph of this chapter.

Table 2-2 presents the elemental composition of the red water used in the mass and energy balance (M&EB) program. The overall heating value for the red water is 487 Btu/lb, which equates to a thermal release of 0.4 MMBtu/hr.

Table 2-1

Composition of Red Water Solids

Parameter	Weight (percent)
Inorganic Salts	
Na_2SO_3-Na_2SO_4	32.3
$NaNO_2$	11.2
$NaNO_3$	1.5
SUBTOTAL	45
Nitrobodies	
Sodium sulfonate of 2,4,5-TNT	22.7
TNT-sellite complex	16.2
Sodium sulfonate of 2,3,4-TNT	7.6
Sodium sulfonate of 2,3,5-TNT	2.0
2,4,6-TNBA	1.0
White compound sodium salt	1.0
TNBAL	1.0
TNBOH	1.0
Sodium nitroformats	2.5
SUBTOTAL	55.0

Table 2-2

Design Basis: Red Water Profile

Description	Physical Form	System Thermal Capacity (MMBtu/hr)	Feed Rate (GPM/[lb/hr])	Elemental Composition (Wt. %)									Heating Value (Btu/lb)	Heat Release (MMBtu/hr)
				C	H_2	O_2	N_2	H_2O	Cl_2	S	Ash	Inert		
Red Water	Liquid	4.5	1.5/[826]	3.00	0.10	3.15	0.95	85.00	0.00	0.65	0.00	7.15	487	0.4

NOTE: Table 2-2 is derived from Table 2-1.

3.0 WASTE FEED CHEMISTRY AND SELECTION OF CIRCULATING MEDIA

3.0 Waste Feed Chemistry and Selection of Circulating Media

3.1 Waste Feed Chemistry

3.1.1 Introduction

CBCs are noted for their high combustion efficiency. This combustion efficiency is due to the turbulence of the combustion gas in the combustion chamber, the abrasive effect of the bed material, and the long solids residence time of typically more than 20 minutes (Brunner, 1991). Because of the high combustion efficiency of CBCs, they typically operate at 1600°F, which is lower than the operating temperature of most other types of incinerators.

One of the problems associated with the operation of CBCs is the formation of low melting point eutectic mixtures in the combustion chambers. These mixtures lead to the agglomeration of the bed into large agglomerates of crude glass. Agglomeration is caused when eutectic mixtures are formed in the combustion chamber with a melting point lower than the CBC operating temperature. When this happens, the CBC has to be shut down and the operators have to manually remove this material from the combustor; therefore, the high melting point bed material is desirable. Additional problems include oxides of nitrogen (NO_x) and sulfur oxides (SO_x) emissions.

3.1.2 Waste Feed Composition

The CBC proposed for this project is designed to burn red water. As indicated in Chapter 2.0, red water comprises 15 to 30 percent solids, which contain about 45 percent inorganic salts. Tables 2-1 and 2-2 present the composition of red water.

Sodium. In the oxidative environment of the CBC, the sodium in the sodium chloride (NaCl) present in the red water solids will combine with oxidized sulfur to form Na_2SO_4 and with carbon dioxide to form Na_2CO_3. Pure Na_2SO_4 has a melting point of 1623°F and pure Na_2CO_3 has a melting point of 1569°F. A mixture of Na_2SO_4 and Na_2CO_3 has a melting point of 1522°F. Additionally, the chlorine in the red water may lead to the formation of

compounds with melting points as low as 1134°F. Table 3-1 presents a list of the compounds of concern and the melting points of their pure forms.

The CBC bed material is typically sand (SiO_2). If present, NaCl can react with the sand to form a viscous sodium-silicate ($Na_2O \bullet 3SiO_2$), which has a melting point of 1175°F:

$$3SiO_2 + 2NaCl + H_2O \rightarrow Na_2O \bullet 3SiO_2 + 2HCl \qquad (1)$$

The sodium nitrite and sodium nitrate will oxidize into NO_x and Na_2O. In the presence of moisture, the Na_2O will form sodium hydroxide (NaOH), which has a melting point of 612°F. NaOH will contribute to the alkalinity of the ash.

If bed materials are silica-sand, or if there is SiO_2 in the red water, the Na_2SO_2 present in red water will react with the silica to form $Na_2O \bullet 3SiO_2$, which is formed in Equation 1:

$$Na_2SO_4 + 3SiO_2 \rightarrow Na_2O \bullet 3SiO_2 + SO_2 + 0.5O_2 \qquad (2)$$

The addition of lime, iron oxide, or aluminum to the bed will raise the melting point of the bed, as indicated below.

Lime Addition. Lime (CaO) addition and SiO_2 will produce devitrite, which melts at 1885°F.

$$Na_2O \bullet 3SiO_2 + 3SiO_2 + 3CaO \rightarrow Na_2O \bullet 3CaO \bullet 6SiO_2 \qquad (3)$$

In the absence of silica, calcium oxide reacts with sodium-silicate to produce a product that melts at 2343°F.

$$Na_2O \bullet 3SiO_2 + CaO \rightarrow Na_2O \bullet 2CaO \bullet 3SiO_2 \qquad (4)$$

Iron Oxide Addition. Iron oxide (Fe_2O_3) addition to sodium-silicate will produce acmite, which melts at 1751°F. However, for this reaction to occur the iron oxide and silica must be available in very fine particles.

Table 3-1

Melting Point of Selected Inorganic Salts

Compound	Chemical Formula	Melting Point (°F)[a]	Remarks
Sodium	Na	208	
Sodium Nitrite	$NaNO_2$	520	Decomposes at 608°F
Sodium Nitrate	$NaNO_3$	586	Decomposes at 716°F
Sodium Hydroxide	$NaOH$	612	
Sodium Chloride	$NaCl$	1472	
Sodium Carbonate	Na_2CO_3	1569	
Sodium Sulfate	Na_2SO_4	1623	
Sodium Sulfite	Na_2SO_3		Decomposes
Sodium Sulfide	Na_2S	1688	

[a] Source: Shackelford and Alexander, 1992.

Table 3-2

Melting Point of Mixture of Fluidized Bed Material and Inorganic Salts

Compound	Chemical Formula	Melting Point (°F)
Addition of Silica (SiO_2)	$Na_2O{\cdot}3SiO_2$	1175
Addition of Iron Oxide (Fe_2O_3)		
Acmite	$Na_2O{\cdot}Fe_2O_3{\cdot}4SiO_2$	1751
Addition of Lime (CaO)		
Devitrite	$Na_2O{\cdot}3CaO{\cdot}6SiO_2$	1885
	$Na_2O{\cdot}2CaO{\cdot}3SiO_2$	2343
Addition of Aluminum Oxide (Al_2O_3)		
Albite	$Na_2O{\cdot}Al_2O_3{\cdot}6SiO_2$	2026
Nepheline	$Na_2O{\cdot}Al_2O_3{\cdot}2SiO_2$	1600
Albite+Nepheline		1954

$$Na_2O{\bullet}3SiO_2 + Fe_2O_3 + SiO_2 \rightarrow Na_2O{\bullet}Fe_2O_3{\bullet}4SiO_2 \qquad (5)$$

Aluminum-Silicate Addition. Kaolin clay is a natural mixture of hydrous aluminum silicates, SiO_2/Al_2O_3, in a ratio of 2:1 to 3:1.

$$Na_2O{\bullet}3SiO_2 + 3SiO_2 + Al_2O_3 \rightarrow Na_2O{\bullet}Al_2O_3{\bullet}6SiO_2 \qquad (6)$$

Aluminum-silicates react with sodium-silicate to form albite. Albite, a sodium-aluminum-silicate, has a melting point of 2026°F. In the absence of silica, aluminum-oxide reacts with sodium-silicate to form nepheline (Wall et al., 1975).

$$Na_2O{\bullet}3SiO_2 + Al_2O_3 \rightarrow Na_2O{\bullet}Al_2O_3{\bullet}2SiO_2 + SiO_2 \qquad (7)$$

Albite and nepheline will form eutectic point at 1954°F. The advantage kaolin clay provides over other clays is its ability to react with NaCl directly to form nepheline.

$$Al_2O_3{\bullet}2SiO_2 + 2NaCl + H_2O \rightarrow 2HCl + Na_2O{\bullet}Al_2O_3{\bullet}2SiO_2 \qquad (8)$$

3.1.3 NO_x Emissions

There are several different sources of NO_x formation in a combustion process, the burning of nitrogen containing organics and high temperature combustion in air being two major sources. The actual NO_x emissions from burning nitrated materials is less than the theoretical potential of all NO components remaining as NO_x, but the emissions are higher for processes in which the burning materials are well mixed with air or oxygen than when mixing is poor. By design, the CBC is a well mixed combustion process, so NO_x emissions from NO components are expected to be relatively high. At 15 percent solids in red water (design case), if 100 percent of the NO components in the red water organics remained as NO_x, over 38 lb/hr of NO_x emissions would result.

NO_x formation increases significantly at combustion temperatures in excess of 2400°F, but only about 0.38 lb/hr is expected to be formed at the relatively low temperature of operation in the CBC. Another source of NO_x emissions from the processing of red water is the decomposition of the sodium nitrite and nitrate salts which account for over 12 percent of the

solids content in the red water. This decomposition could add over 10 lb/hr of NO_x emissions.

The emissions of NO_x would be 170 tons per year (at 15 percent solids in red water) if 100 percent of all the potential formation occurred. This rate is below the 250 ton per year PSD limit for new sources, but the limit is site specific. Typically 100 percent of theoretical formation of NO_x does not occur. Pilot testing of a solid nitrogenated waste in a rotary kiln indicated that 6 to 12 percent of the nitrogenated group remained as NO_x. The percentage decreased as the feed rate of solid waste was increased, which increased the depth of the solids bed and decreased the exposure of the solids to combustion air. The solids bed in a rotary kiln is not very well mixed with combustion air, so the NO_x conversion is expected to be lower than in the CBC.

Liquid testing with a mono-nitrated aromatic compound indicated that 13 to 33 percent of the nitrogenated bodies remained as NO_x. The liquid was fired through an atomized nozzle, and the NO_x emissions could be modified by the degree of atomization. The lower feed rates which were more highly atomized had the highest percentage retention or formation of NO_x. During one test when the feed rate was held constant and the degree of atomization was increased, the NO_x emissions increased by 25 percent.

If the NO_x emissions were 25 percent of maximum theoretical, the emissions would be 42.5 tons per year, and the stack concentration would be 1,535 parts per million (ppm) on a dry basis. One of the goals of the pilot testing will be to evaluate the percentage of theoretical NO_x emissions formed. The stack off-gases during the pilot testing will also have to be observed for the reddish-brown visual emissions of high concentrations of NO_x.

NO_x emissions control options include:

- Thermal deNO_x systems
- Catalytic reactor deNO_x systems
- DeNO_x scrubbers.

Thermal $deNO_x$ systems inject urea solution or ammonia into the gas stream at 1600 to 1800°F. NO_x emission reductions of up to 50 percent can be achieved by thermal $deNO_x$ systems.

Catalytic reactor $deNO_x$ systems inject ammonia into a reactor located upstream of the I.D. fan. The ammonia converts the NO_x into N_2 and water. NO_x emission reductions of up to 80 percent can be achieved by catalytic reactor $deNO_x$ systems.

$DeNO_x$ scrubbers convert NO into NO_2 in an oxidizing scrubber. The NO_2 is then converted to N_2 in a reducing scrubber. NO_x emission reductions of up to 90 percent can be achieved by $deNO_x$ scrubbers.

Thermal $deNO_x$ systems are relatively inexpensive compared to catalytic reactor $deNO_x$ systems and $deNO_x$ scrubbers. All units can be retrofitted to the CBC if required.

3.1.4 Sulfur Dioxide Emissions

Based on the waste profile composition, sulfur dioxide (SO_2) will be generated from two sources. The first source is the organic sulfur present in the nitrobodies; the second is from the reaction of sodium sulfate with sand. (See Equation 2.) Estimated SO_2 emissions from the incineration of red water is 28.8 lb/hr, which equals 3,292 parts per million dry volume (ppmdv) in the stack gas. Maximum SO_2 emissions from the incineration of red water at 30 percent solids is 58 lb/hr, which equals 6,584 ppmdv in the stack gas.

To reduce SO_2 emissions, lime or limestone may be injected on top of the bed. Lime consumption is expected to be approximately 25 lb/hr. Maximum lime consumption is 50 lb/hr, when processing red water at 30 percent solids. SO_2 emissions and lime consumption calculations are included in this chapter.

3.1.5 Hydrocarbon Emissions

The emissions of total hydrocarbons (THC) or products of incomplete combustion (PIC) from an incineration process vary with the types of wastes being burned, as well as with the type of incineration system and the combustion parameters. The EPA "Guidance on PIC Controls

for Hazardous Waste Incinerators" (EPA/530-SW-90-040, April 1990) states that when CO emissions are less than 100 ppm, the PIC emissions will be low levels of concern relative to health risk. The combustion efficiency of the CBC should be such that the CO emissions will be well below 100 ppm.

Methane and other light hydrocarbons are typical PICs. The referenced guidance document lists commonly detected carcinogenic and noncarcinogenic PIC emissions, with C1 and C2 hydrocarbons being by far the largest quantities listed (9,600 and 17,000 nanograms per liter [ng/L], respectively). Other significant quantities of hydrocarbons listed include benzene (4,500 ng/L), chloroform (1,40 ng/L), methylene chloride (2,800 ng/L), formaldehyde (780 ng/L), and toluene (550 ng/L). The guidance listing is a compilation of data from many different combustion processes.

IT has evaluated PIC emissions from several different systems and trial burns. When operating a rotary kiln/secondary combustion chamber system at a relatively low temperature in the SCC of 1730°F, the only significant quantities of carcinogenic and noncarcinogenic PICs detected were benzene (71 ng/L), carbon tetrachloride (1.2 ng/L), chloroform (74 ng/L), chloromethane (170 ng/L), toluene (3.8 ng/L), bromoform (366 ng/L), and dibromochloromethane (25 ng/L). Benzene, carbon tetrachloride, chloroform, and toluene were all two orders of magnitude less than the average levels cited in the guidance document. The source of PICs cannot always be defined. For instance, in the test cited, the chlorinated PICs were probably the result of feeding a chlorinated POHC as part of the test, but the source of the bromine that resulted in the brominated PICs has not been determined.

As an indication of good combustion, the measurement of THC levels should be one of the goals of the CBC pilot testing.

3.2 Bed Material Selection

In a CBC, the auxiliary fuel and red water are burned in the bed material. Therefore, the properties of the bed material are critically important to the performance of the CBC. It is the chemical property of material (i.e., high melting point) that will prevent agglomeration, and not the concentration of the bed material. Therefore, bed material that forms a high

melting point eutectics is desirable in preventing agglomeration in the CBC. The following bed materials were considered for this application:

- Aluminum oxide (Al_2O_3)
- Ceramic material
- Dolomite [$CaMg(CO_3)_2$]
- Gabbro
- Granite
- Kaolin clay (Al_2O_3•$2SiO_2$•$2H_2O$)
- Lime (CaO)
- Quartz (SiO_2)
- Silica sand (SiO_2)
- Zirconium (IV) oxide (ZrO_2)
- Mixtures of these materials.

These materials were compared on the basis of:

- Chemical properties
- Physical properties
- Price and availability.

3.2.1 Chemical Properties

As mentioned previously in Section 3.1, Waste Feed Chemistry, agglomeration is a major concern when operating a CBC. The proper bed material will not combine with one of the components of the red water to form a low melting point eutectic mixture. For example, SiO_2 will combine with the sodium in the red water to form eutectic materials (Table 3-2); however, the formation of the eutectic mixtures may be prevented with the addition of Fe_2O_3, CaO, or aluminum silicate. These additives have to be continuously added in the correct proportions to the CBC when thermally treating red water. If the quantity of the Fe_2O_3, CaO, or aluminum silicate was not correct, if the additive was not evenly blended with the bed material, or if other chemicals combined with the additive before the additive reacted with the sodium silicate, agglomeration will occur, leading to CBC shutdown and maintenance. Therefore, for ease of operation, it was decided to initially consider bed materials that do not contain SiO_2. However, if the evaluation indicated that the other materials were not suitable, then SiO_2-containing bed materials would be reconsidered. Therefore, gabbro, granite, kaolin clay (Al_2O_3•$2SiO_2$•$2H_2O$), quartz (SiO_2), and silica sand (SiO_2) were initially eliminated from

the list of possible bed materials. Additionally, dolomite and zirconium oxide were removed from consideration because dolomite typically contains SiO_2 and zirconium oxide is purchased as zircon sand, which is a mixture of zirconium oxide (typically less than 2 percent) and SiO_2.

The following materials remain for further consideration:

- Al_2O_3
- Ceramic material
- CaO.

3.2.2 Physical Properties

Agglomeration can be delayed or eliminated by maintaining good combustion circulation and by carefully selecting the bed materials. A CBC with poor circulation will develop localized hot spots where agglomeration of the bed material will start. By maintaining the proper air flow rates and selecting a bed material with the proper physical properties, good circulation can be maintained and hot spots prevented.

Consistent physical properties are required for CBC bed material. Variations in physical properties, including particle size and resistance to breakage, can lead to unwanted operational changes. Consistent bed material properties and CBC operation is particularly important in the pilot-scale CBC. Red water from different sources may be tested in the CBC and, if the bed material varies from batch to batch, the results of the pilot tests may be obscured.

Properly sized bed material will properly circulate in the CBC, with only small quantities of bed material escaping the combustion system through the cyclone. If the size of the bed material particles is too large, the particles will not be entrained in the combustion gases, not be separated from the combustion gases in the cyclone, and not be returned through the loop-seal to the combustion chamber. This process can lead to localized hot spots and poor combustor performance. If the size of the particle is too small, the particles will be entrained in the combustion gases but will not be separated from the combustion gases by the cyclone. This result will increase the operational requirements of the gas cleaning system. The optimum size of the bed particles is about 250 microns.

The abrasive action of the bed material and the combustion gases will continually degrade the bed material particles and reduce their size. Friable particles will degrade rapidly in this environment, resulting in increased particulate loading to the gas cleaning system and frequent addition of material to the CBC to maintain the pressure drop across the bed. Therefore, the ability of the bed material to maintain particle size is important.

CaO can be purchased in the desired particle size. CaO is very friable, which will necessitate the continual addition of CaO to the bed and will increase the particulate removal requirements of the gas cleaning system. Therefore, CaO was eliminated from further consideration as the primary bed material.

Ceramic materials are mixtures of aluminum, calcium, and magnesium. The composition of these mixtures can change from region to region and from batch to batch. Depending on the chemical composition of the ceramic material such as CaO and Fe_2O_3, it is possible that some of the sticky sodium compounds such as Na_2SO_4, Na_2SO_4-NaCl mixture, and $Na_2O \bullet SiO_2$ will form. Therefore, ceramic materials were eliminated from further consideration.

The only material remaining for further consideration is Al_2O_3. Per Section 3.1, aluminum oxide will form a high melting point mixture with inorganic solids present in red water. It is this superior quality along with its heat transfer characteristics that distinguishes it from other candidates.

3.2.3 Price and Availability

To prevent a buildup of sodium and eutectic mixtures with a low melting point in the bed, bed material will be continuously added to the CBC, and ash and bed material continuously removed from the combustion chamber by the ash cooler conveyor. Initially, a feed rate of 1.5 times the molar quantity of sodium in the waste feed is recommended, with optimization of the feed rate during CBC operation (Dorr-Oliver, 1994). The recommended initial Al_2O_3 feed rate is 43.5 lb/hr. Calculations are included in this section.

Al_2O_3 is widely available and costs approximately $790 per ton. With a recommended Al_2O_3 feed rate (after start-up) of less than 50 lb/hr, Al_2O_3 is an economically acceptable bed material.

3.2.4 Selected Bed Material

Based on chemical, physical, and price considerations, Al_2O_3 is the selected bed material. Al_2O_3 is available in the desired particle size, about 250 microns. Al_2O_3 will slowly decrease in size, resulting in a long bed life.

Agglomeration is not expected when using Al_2O_3 as the bed material. In the presence of sodium, Al_2O_3 forms sodium-aluminum silicates that have melting points in the 1600 to 2025^oF temperature range. These melting points are hot enough to prevent agglomeration during the combustion of red water, provided the CBC is operated in the 1500 to 1600^oF-temperature range. However, to prevent a buildup of eutectic materials in the bed, the continuous addition of bed material to the CBC and the continuous removal of ash and bed material from the combustion chamber, is recommended (Mullen, 1988; Zakkey et al., 1984; Goblirsch et al., 1983).

Al_2O_3 meets the chemical, physical, and cost requirements for bed materials when burning red water; therefore, Al_2O_3 is the recommended bed material.

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By SKZ Date 1/3/95 Subject CBC Sheet No. 1 of 1
Chkd. By ____ Date ____ Determine Burner NOx Emission Proj. No. 322243

Objective:

Determine NO_x emission from CBC Burner, for the incineration of Red water

Assumptions:

1- NO_x level from burner is 60 ppm

Calculation Basis

CBC Flue Gas Flow = 528.6 lb/hr @ 1600 °F & 406.8" w.c.
= 201.1 lb mole/hr
= 136.7 lbmole/hr (Dry)

Methodology:

Total NO_x = Red water + Thermal (NO_x) from Burner

$$\text{Thermal } NO_x \text{ from Burner} = \frac{60\times10^{-6} \mid 136.7 \text{ lbm} \mid 46.1\text{b}}{\mid \text{hr} \mid \text{lbm}}$$

NO_x = 0.38 lb/hr

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(1)

By CP Date 12/29/94 Subject USAEC CBC Emissions Sheet No. 1 of 2

Chkd. By ___ Date ___ Proj. No. [illegible]

Feed	Wt %	Assumed Formula	Atm Wt
$Na_2SO_3 - Na_2SO_4$	32.3	(50-50)	268
$NaNO_2$	11.2		69
$NaNO_3$	1.5		85
Sodium sulfonate of 2,4,5-TNT	22.7	$C_7H_5N_3O_9NaS$	330
TNT-sulfite complex	16.2	$C_7H_5N_3O_6 - Na_2SO_3$	353
Sodium sulfonate of 2,3,4-TNT	7.6	$C_7H_5N_3O_9NaS$	330
Sodium sulfonate of 2,3,5-TNT	2.0	$C_7H_5N_3O_9NaS$	330
2,4,6-TNBA (Na salt)	1.0	$C_8H_4N_3O_8Na$	293
White compound sodium salt	1.0		
TNBAL	1.0	$C_8H_3N_3O_7$	255
TNBOH	1.0	$C_7H_5N_3O_7$	243
Sodium nitroformate	2.5	$C_7H_4N_3O_7Na$	265

Basis: 826 lb/hr red water feed at 15% solids (124 lb/hr)
Flue gas 528.6 lb/hr, 136.7 lbmol/hr dry (slightly different)

Potential NO_x emissions

$NaNO_2$	11.2% × 124 lb/hr	× $\frac{46}{69}$ wt fr	=	9.26
$NaNO_3$	1.5% × 124	× $\frac{46}{85}$	=	1.01
NaS of TNT	22.7 × 124	× $\frac{3\times46}{330}$	=	11.77
TNT-sulfite	16.2 × 124	× $\frac{3\times46}{353}$	=	7.85
NaS of 2,3,4-TNT	7.6 × 124	× $\frac{3\times46}{330}$	=	3.94
NaS of 2,3,5-TNT	2.0 × 124	× $\frac{3\times46}{330}$	=	1.04
TNBA	1.0 × 124	× $\frac{3\times46}{293}$	=	0.58
TNBAL	1.0 × 124	× $\frac{3\times46}{255}$	=	0.67
TNBOH	1.0 × 124	× $\frac{3\times46}{243}$	=	0.70
Na nitroformate	2.5 × 124	× $\frac{3\times46}{265}$	=	1.61
				38.43 lb/hr NO_2

Burner NO_x contribution (from SKZ 9/22/94) 0.38 lb/hr

38.81 ÷ 46 = 0.84 mol/hr

108-10-85

INTERNATIONAL TECHNOLOGY CORPORATION

1

By CP Date 12/29/94 Subject USAEC CBC Emissions Sheet No. 2 of 2

Chkd. By ____ Date ____ Proj. No. 322243

Annual NO_x emissions 38.81 lb/hr × 8760 hr/yr = 340,000 lb/yr

= 170 tons/yr

Maximum concentration 0.84 mol/hr ÷ 136.7 mol/hr = 6140 ppm (dry)

Note: These are maximum values based on 100 percent conversion of all nitro bodies to NO_x. A much lower conversion rate is typically experienced.

INTERNATIONAL TECHNOLOGY CORPORATION

By SKZ Date 9/22/94 Subject CBC Sheet No. 1 of 3

Chkd. By ___ Date ___ SO_2 Emission from CBC Proj. No. 322243.002.03.01

OBJECTIVE:

Determine SO_2 emission from CBC and Determine quantity of lime required for neutralization.

Calc. Basis:

The sources of SO_2 are (A) organic component of red water, and (B) from sodium sulfate.

(A) SO_2 from organic sulfur:

From HMB dated 9/9/94 by: SLM Datafile: U3AC.DAT

$$SO_2 = 10.719 \text{ lb/hr} = 0.167 \text{ lbm/hr}$$

(B) Assume all $Na_2SO_3 - NaSO_4$ is in Na_2SO_4 form at 32.3% of solids.

Assume that Na_2SO_4 will react with SiO_2 according to this RXN

$$Na_2SO_4 + 3\,SiO_2 \longrightarrow Na_2O \cdot 3SiO_2 + SO_2\uparrow + 0.5O_2$$

$$Na_2SO_4 \text{ in the feed} = \frac{32.3}{100} \text{ wt.\%} * \frac{123.9 \text{ lb}}{\text{hr}} = 40.02 \frac{\text{lb}}{\text{hr}}$$

Potential SO_2 formed from the above RXN

$$SO_2 = \frac{40.02 \cancel{\text{lb}}}{\text{hr}} \; \frac{\cancel{\text{lbm}}\, Na_2SO_4}{142.06 \cancel{\text{lb}}} \; \frac{\cancel{\text{lbm}}\, SO_2}{\cancel{\text{lbm}}\, Na_2SO_4} \; \frac{64.06 \text{ lb}}{\cancel{\text{lbm}}\, SO_2} = \frac{18.05 \text{ lb}}{\text{hr}}$$

$$SO_2 \text{ emission} = 10.719 \frac{\text{lb}}{\text{hr}} + 18.05 \frac{\text{lb}}{\text{hr}} = 28.8 \text{ lb/hr}$$

Summary

1. $\boxed{SO_2 \text{ emission from CBC} = 28.8 \text{ lb/hr}}$

$$SO_2 \text{ Conc.} = \frac{28.8 \text{ lb}}{\text{hr}} \; \frac{\text{lbm } SO_2}{64 \text{ lb}} \; \frac{\text{hr}}{136.7 \text{ lbm}} = \boxed{3{,}292 \text{ ppmv dry}}$$

INTERNATIONAL TECHNOLOGY CORPORATION

By SKZ Date 11/10/94 Subject CBC Sheet No. 2 of 3

Chkd. By ___ Date ___ SO_2 Emission from CBC Proj. No. 322243.002.03.00

Summary (Continued)

2. At 30% solids in red water,

Maximum SO_2 emission from CBC = $\boxed{\text{58 lb/hr}}$

Max. SO_2 concentration = $\boxed{\text{6584 ppmv (dry)}}$

INTERNATIONAL TECHNOLOGY CORPORATION

2

By SKZ Date 9/22/94 Subject CBC Sheet No. 3 of 3

Chkd. By ____ Date ____ Lime addition to CBC Proj. No. 322243.002.03.001

OBJECTIVE:

Determine quantity of lime addition required for neutralization of SO_2 resulting from the incineration of Ret Water.

Calc Basis

$$CaO + H_2O \longrightarrow Ca(OH)_2 \quad — (1)$$

$$SO_2 + Ca(OH)_2 \longrightarrow CaSO_3 + H_2O \quad — (2)$$

Calculate ratio CaO / SO_2:

RXN (1)

$$= 1 \text{ lb } CaO \; \frac{\cancel{\text{lbm}}\ CaO}{56.08 \text{ lb}} \; \frac{\text{lbm } Ca(OH)_2}{\cancel{\text{lbm}}\ CaO} \; \frac{74 \text{ lb } Ca(OH)_2}{\text{lbm}} = 1.32 \; \frac{\text{lb } Ca(OH)_2}{\text{lb } CaO}$$

RXN (2)

$$= 1 \text{ lb } SO_2 \; \frac{\cancel{\text{lbm}}\ SO_2}{64 \text{ lb}} \; \frac{\text{lbm } Ca(OH)_2}{\cancel{\text{lbm}}\ SO_2} \; \frac{74 \text{ lb } Ca(OH)_2}{\text{lbm}} = 1.16 \; \frac{\text{lb } Ca(OH)_2}{\text{lb } SO_2}$$

$$\frac{1.16 \text{ lb } \cancel{Ca(OH)_2}}{\text{lb } SO_2} * \frac{\text{lb } CaO}{1.32 \text{ lb } \cancel{Ca(OH)_2}} = 0.88 \; \frac{\text{lb } CaO}{\text{lb } SO_2}$$

$$\text{Lime for neutralizing } SO_2 = \frac{28.8 \text{ lb}^{SO_2}}{\text{hr}} \; \frac{0.88 \text{ lb } CaO}{\text{lb } SO_2}$$

$$\boxed{\text{lime} = 25. \text{ lb/hr } CaO}$$ at 15% solids

$$\boxed{\text{Max. lime at 20\% Solids} = 50 \text{ lb/hr } CaO}$$

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By SKZ Date 9/22/94 Subject CBC Sheet No. 1 of 2

Chkd. By ____ Date ____ Proj. No. 322243.0002.03.01

OBJECTIVE: Determine quantity of Aluminum Silicate required

Calc. Basis: Based on recommendations of Dorr-Oliver to add aluminum silicate at 1.5 times molar quantity of Na present in the waste.

$$Na_2SO_4 + 3\,SiO_2 \longrightarrow Na_2O\cdot 3SiO_2 + SO_2 + 0.5\,O_2 \qquad \text{Rxn } 1$$

$$Na_2O\cdot 3SiO_2 + 3\,SiO_2 + Al_2O_3 \longrightarrow Na_2O\cdot Al_2O_3\cdot 6\,SiO_2 \qquad \text{RXN } 2$$

Calculate the ratio of $\frac{Al_2O_3}{Na_2SO_4}$

From 1st RXN, $\frac{1\text{ lb } Na_2SO_4}{} \; \frac{\text{lbm } Na_2SO_4}{142.06\text{ lb}} \; \frac{\text{lbm } Na_2O\cdot 3SiO_2}{1\text{ lbm } Na_2SO_4} \; \frac{242.2\text{ lb}}{\text{lbm } Na_2O\cdot 3SiO_2}$

$$= 1.71\ \frac{Na_2O\cdot 3SiO_2}{Na_2SO_4}$$

From 2nd RXN, $1\text{ lb } Na_2O\cdot 3SiO_2 \; \frac{\text{lbm } Na_2O\cdot 3SiO_2}{242.2\text{ lb}} \; \frac{\text{lbm } Al_2O_3}{1\text{ lbm } Na_2O\cdot 3SiO_2} \; \frac{101.96\ Al_2O_3}{\text{lbm}}$

$$= 0.42\ \frac{\text{lb } Al_2O_3}{\text{lb } Na_2O\cdot 3SiO_2}$$

$$\frac{Al_2O_3}{Na_2SO_4} = 0.42\ \frac{\text{lb } Al_2O_3}{\text{lb } Na_2O\cdot 3SiO_2}\ \frac{1.71\ Na_2O\cdot 3SiO_2}{Na_2SO_4} = \boxed{0.72\ \frac{\text{lb } Al_2O_3}{\text{lb } Na_2SO_4}}$$

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(3)

By SKZ Date 9/22/94 Subject CBC Sheet No. 2 of 2

Chkd. By ___ Date ___ Proj. No. 322243.002.03.01

Quantity of Al_2O_3 required $= 0.72 \frac{lb\ Al_2O_3}{lb\ Na_2SO_4} \frac{1.5\ lbm\ Al_2O_3}{lbm\ Na_2SO_4} \frac{101.96\ MW\ Al_2O_3}{142.06\ MW\ (Na_2SO_4}$

$= 0.78 \frac{lb\ Al_2O_3}{lb\ Na_2SO_4}$

Quantity of Na_2SO_4 present in the Red Water = 32.3

Assume all inorganic salt present in Red Water is Na_2SO_4,

then Na_2SO_4 = 45 wt.%

Total Na_2SO_4 $= 0.45 * \frac{123.9\ lb}{hr} = \frac{55.8\ lb}{hr}\ Na_2SO_4$

Total Al_2O_3 required $= \frac{55.8\ lb}{hr}\ Na_2SO_4\ \frac{0.78\ lb\ Al_2O_3}{lb\ Na\ SO_4}$

$$\boxed{\text{Total } Al_2O_3 = 43.5\ lb/hr \text{ of } Al_2O_3 \text{ to CBC}}$$

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RECORD OF Telecon Meeting

Project Number	Phase	Task	Subtask
322243	002	03	001

Project Name: US Army Environmental Center

Date: September 13, 1994

Time: 9:43

Call From
Call To X

Name: ~~Luke~~ Lew Clark

Title:

Telephone Number: 203/876-5534

Company Name: DORR-OLIVER

Address:

City

State CT

Zip Code

Other Participants - Name/Location/Representing:

Topic: Fluidized Bed Material

Summary (Decisions & Specific Actions Required by Named Persons):

Q. What is your recommendation for the bed material for the incineration of red water?

A. Neutral agent such as Kaolin Clay, which has aluminum silicate component. Na-Al forms a high melting point salt.

Q. What is the quantity of kaolin clay to be added to the bed?

A. Usually start with 1.5 x Na present, then operation will optimize the quantity.

Q. What do you recombed for SO removal, and NOx removal/reduction?

A. Ammonia & Urea injections in the gas will get 80% reduction. However, Dorr-Oliver has a proprietary system that is sold with the fluidized bed only will result is 60-70% reduction.

Q. What is the recommended operating temperature of the fluidized bed when incinerating red water?

A. 1500- 1600 F.

Required Action:

None

Prepared by (Print/Signature): Saleem K. Zwayyed

Distribution:
Original to Project File: A2
Project Manager
Preparer

✓ Other Distribution (By Preparer):

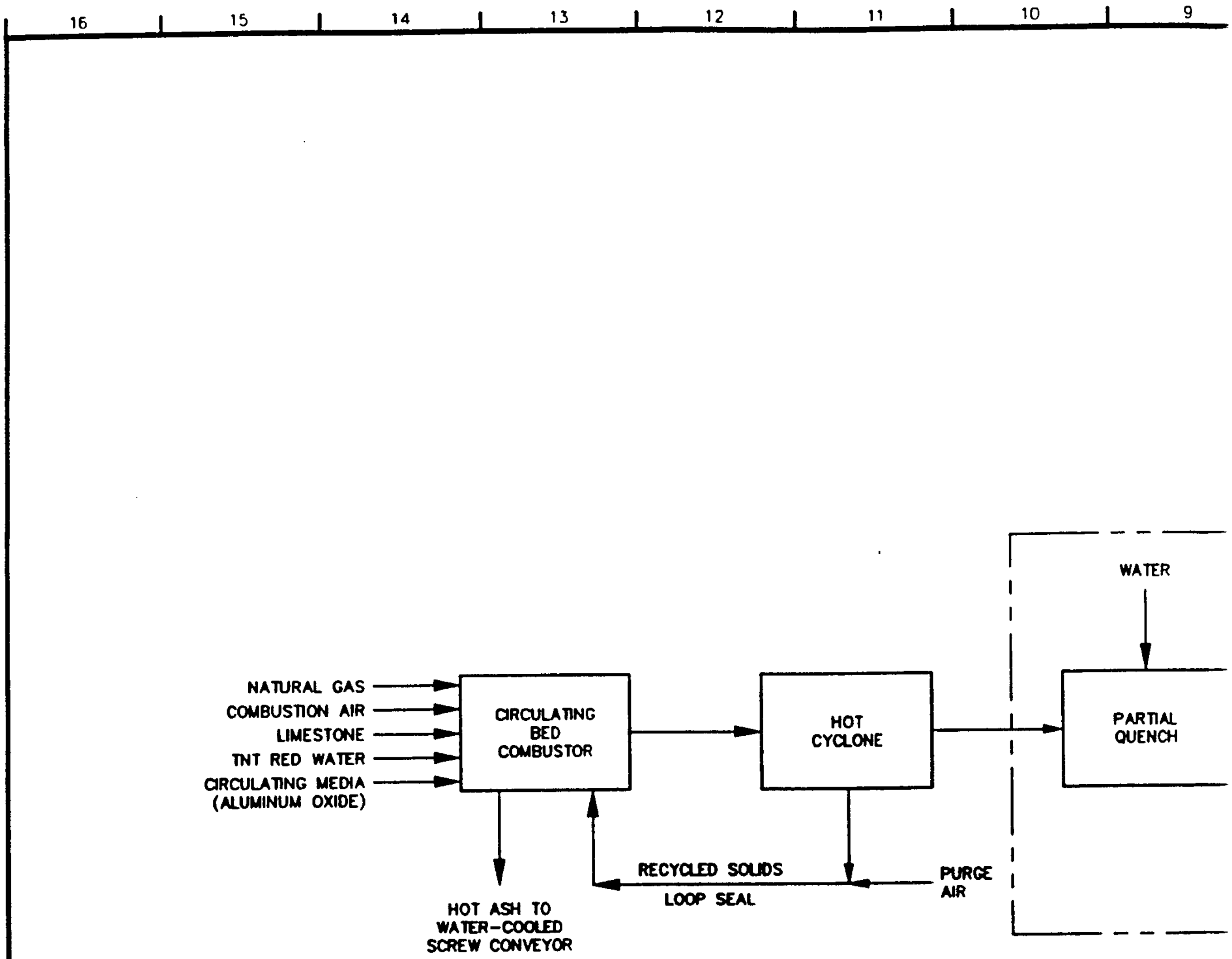
File:phonelog.010

4.0 BLOCK FLOW DIAGRAM

4.0 Block Flow Diagram

The block flow diagram (Drawing D-00-00-001) presented in this chapter is a conceptual representation of the incineration system. A schematic (Drawing D-00-00-002) of the incineration system is also presented. The system consists of a CBC, the combustion chamber, hot cyclone, loop-seal, and an air pollution control system (APCS), which includes partial quench, baghouse, I.D. fan, and a stack.

Red water is incinerated in the combustion chamber. The hot cyclone separates the hot gases from the bed material. The bed material is recycled to the combustion chamber via the loop-seal. The 1600^{o}F combustion gas is cooled to approximately 450^{o}F by spraying water into the incoming hot gas. The partially cooled gas at 450^{o}F then enters the baghouse for particulate removal. The I.D. fan then exhausts the cleaned gases to the atmosphere through the stack.

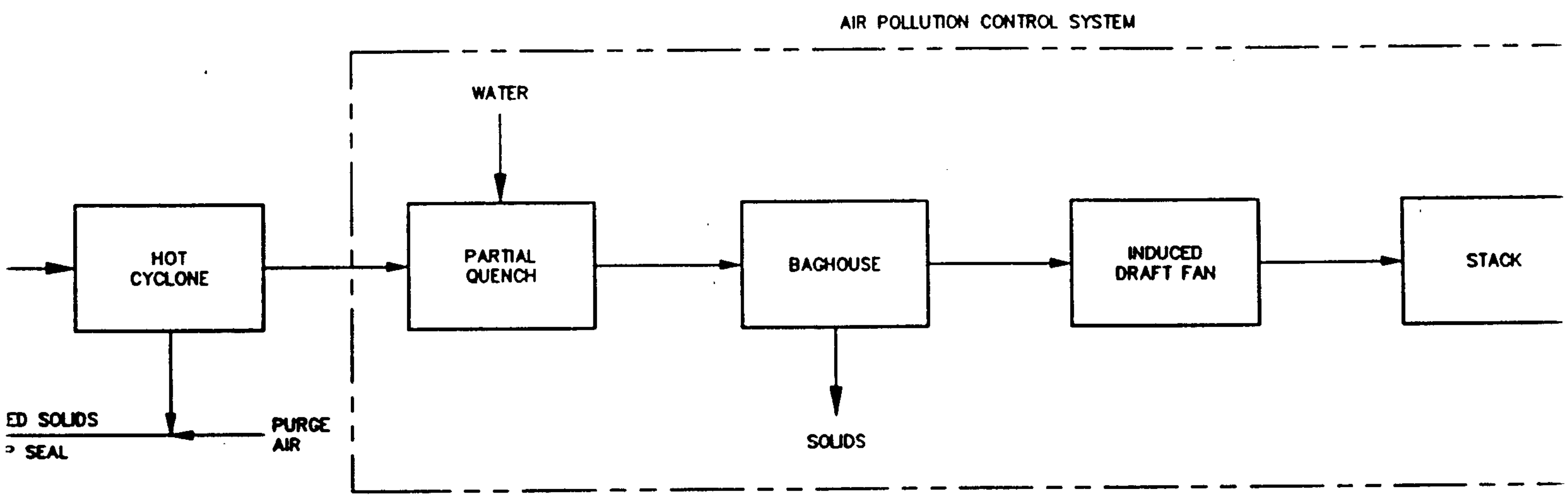


32224308 12/07/94 2:55pm JMH

NOTES

1

12 11 10 9 8 7 6 5 4



(2)

NO	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR
A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	JMH	PA	PA	PA	PA	

STARTING DATE 8/26/94	INITIATOR PA	CHKD PA	DRAWN JMH	CHKD PA	PROJECT MGR P. ACHARYA	

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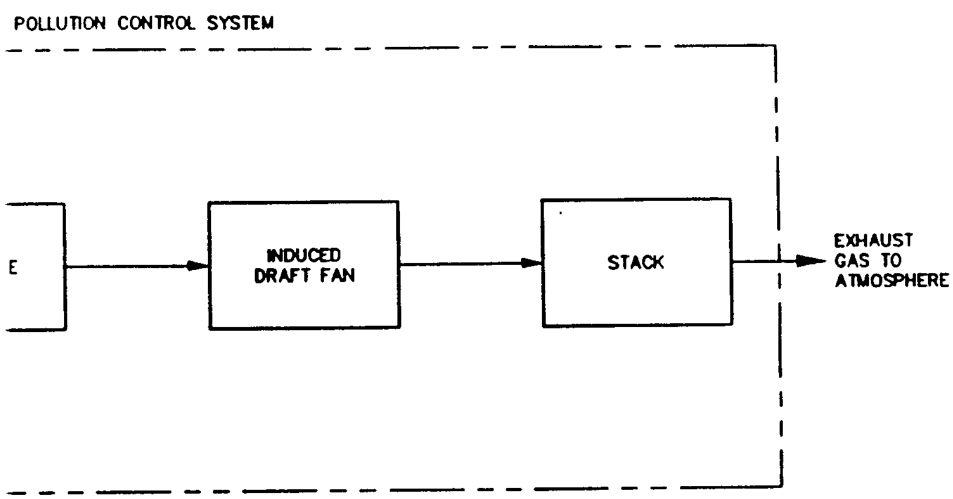
7 6 5 4 3 2 1



A B C D E F G H I J

(3)

JMH	PA	PA	PA	PA	
BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR

MH / CHKD PA | PROJECT MGR P. ACHARYA

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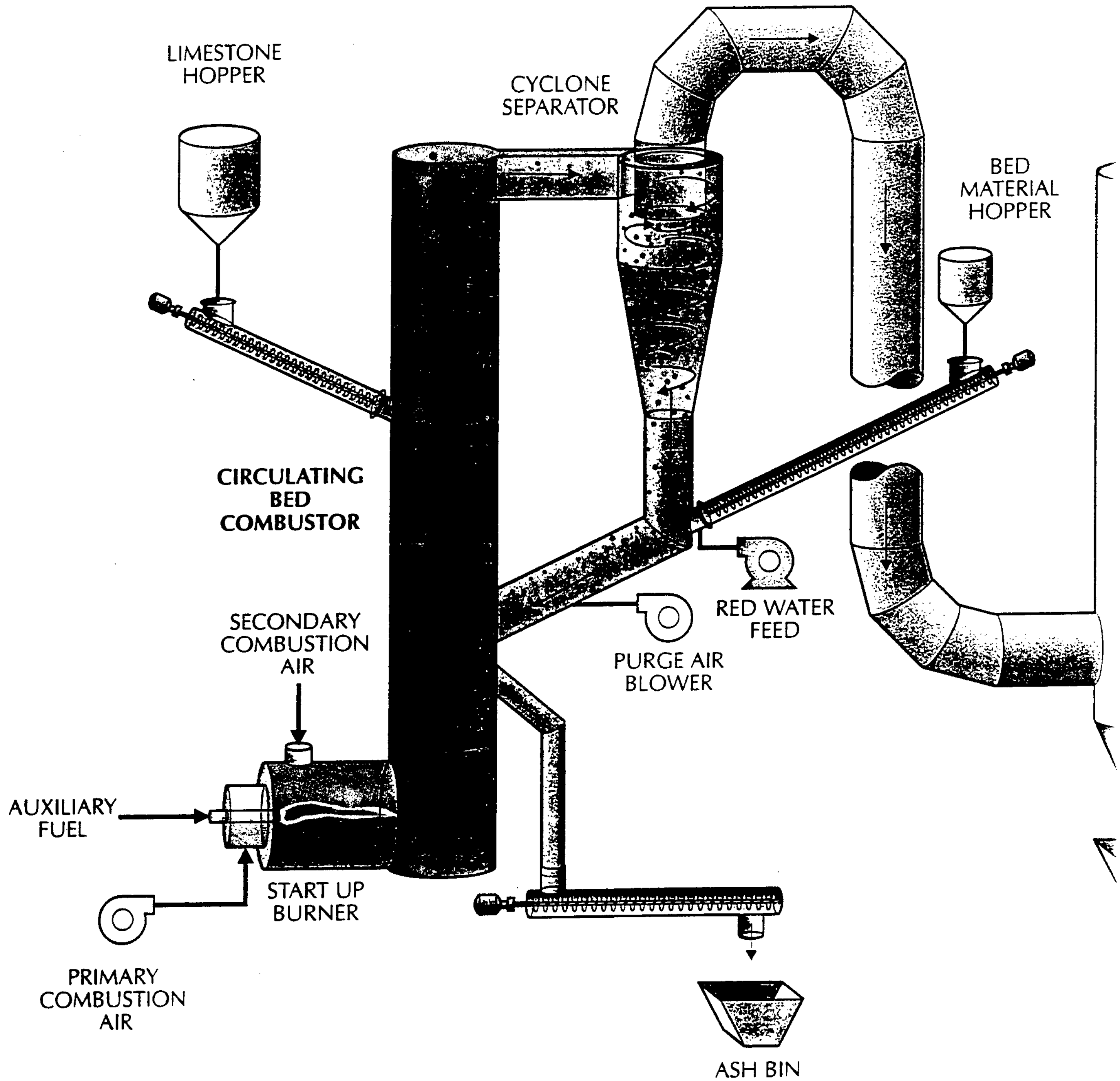
Knoxville, Tennessee

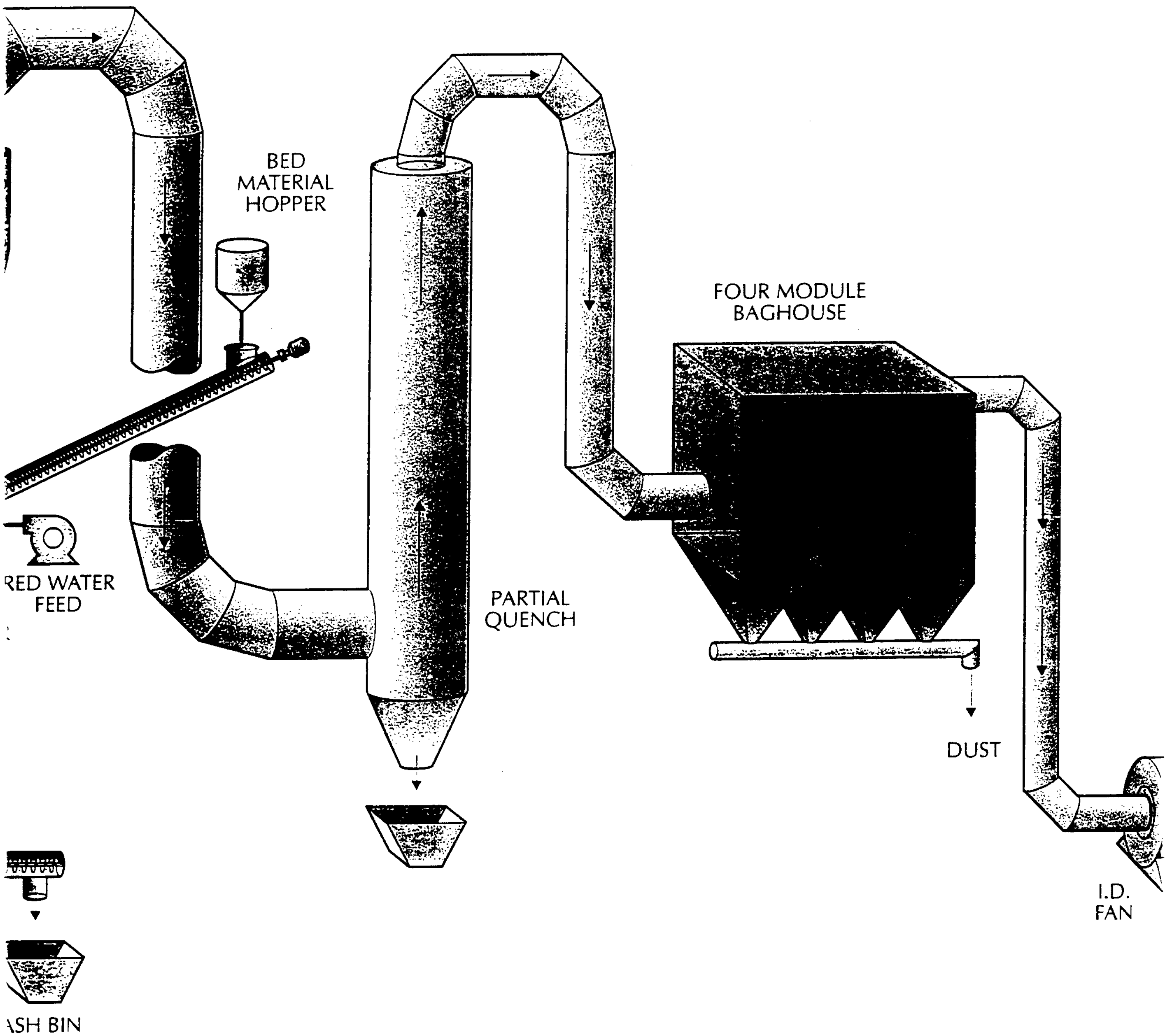
U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

BLOCK FLOW DIAGRAM
INCINERATION SYSTEM

PROJ. NO.	DRAWING NO.	REV
322243	D-00-00-001	A

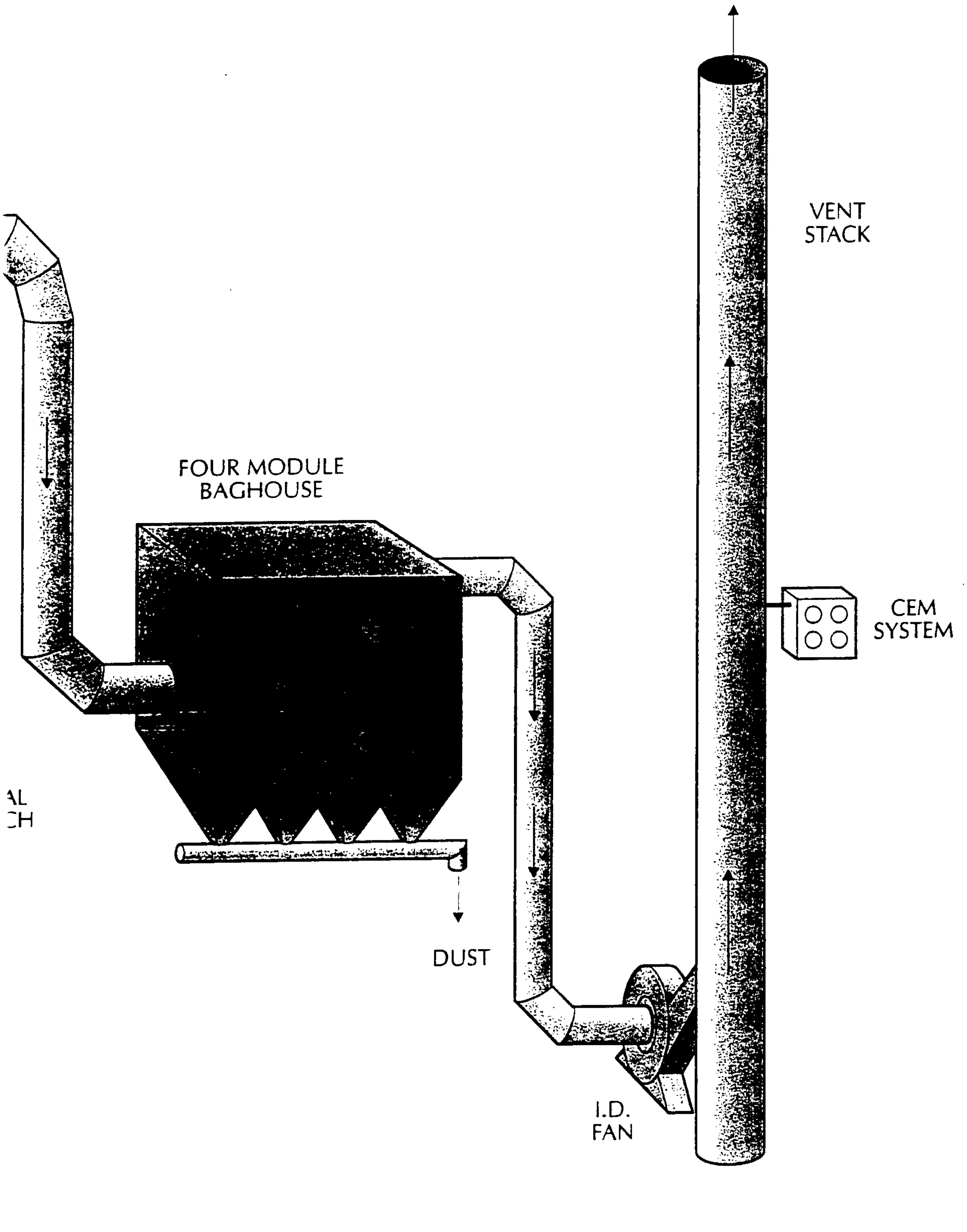


Drawing No.
CIRCULATING BED COMBU



Drawing No. D-00-00-002
CULATING BED COMBUSTOR SYSTEM SCHEMATIC

2



02
TEM SCHEMATIC

5.0 CONCEPTUAL DESIGN BASIS

5.0 Conceptual Design Basis

Table 5-1 presents the conceptual design basis for the TNT red water incineration pilot plant. This table includes the gas flow rate, temperature, and gas composition exiting each of the major pieces of equipment in the system. These parameters are presented for the cyclone exit gas, partial quench exit gas, baghouse exit gas, and stack exit gas. The information presented is for the normal operational case and for the start-up case. The design gas flow and temperature in this table are used for sizing each piece of the major equipment in the system.

The gas flow rate, temperature, and gas composition information presented in Table 5-1 are gathered from the M&EB outputs for the normal case and start-up case included in Chapter 12.0. The PFDs and P&IDs presented in Chapter 7.0 provide more detailed information on design basis.

Table 5-1

Conceptual Design Basis for the TNT Red Water Incineration Pilot Plant[a]

Components	Units	Cyclone Exit Gas (Normal/Start-Up)	Partial Quench Exit Gas (Normal/Start-Up)	Baghouse Exit Gas (Normal/Start-Up)	Stack Exit Gas[b] (Normal/Start-Up)
Water Vapor	lb/hr	1150/151	2706/477	2706/477	2706/477
CO_2	lb/hr	584/168	584/168	584/168	584/168
N_2	lb/hr	3261/1218	3851/1342	3851/1342	3851/1342
O_2	lb/hr	219/126	397/164	397/164	397/164
HCl	lb/hr	0/0	0/0	0/0	0/0
SO_2	lb/hr	11/0	11/0	11/0	11/0
Inert/Salt	lb/hr	59/0	59/0	0.6/0	0.6/0
TOTAL	lb/hr	5285/1663	7608/2150	7550/2150	7550/2150
Gas Flow	acfm[a]	5027/1277	3439/903	3617/950	3444/905
Design Gas Flow	acfm	5027 @ 1600°F	3439 @ 439°F	3617 @ 439°F	3444 @ 461°F

[a]This information is gathered from the mass and energy balances performed for the normal and start-up case included in Chapter 12.0. The red water feed rate and the natural gas flow rates for the normal case are 826 lb/hr and 182 lb/hr, respectively.
[b]Stack exit gas hotter than baghouse exit gas due to flue gas reheat caused by the I.D. fan.
NO_x concentration in the gas will be determined based on the pilot-plant study.

6.0 PROCESS DESCRIPTION

6.0 Process Description

6.1 General Process Overview

The CBC is responsible for the thermal destruction of wastes fed from the waste receiving, storage, and handling areas. Red water is pumped from a waste storage area (by others) to the CBC where it is volatilized and oxidized. The resulting off-gases, which include circulating media comprising aluminum oxide and limestone, enter a hot cyclone (to recover the circulating media from the gases) before they are sent to the APCS. The circulating media is then returned to the bottom of the CBC through a loop-seal that connects the bottom of the cyclone to the CBC bed. The ash from the CBC bed is continuously purged through the ash cooler conveyor and dropped into an ash bin. The gases from the cyclone pass through a partial quench for cooling in preparation for particulate removal in a baghouse. The baghouse removes more than 99 percent of the particulate entrained in the gas. The gas then enters an I.D. fan and exits through a stack.

The CBC is designed to process 1.5 gpm of red water (heating value, 487 British thermal units per pound [Btu/lb]) with a heat release of 0.4 MMBtu/hr. The total thermal input (due to red water and auxiliary fuel) to the system is 4.5 MMBtu/hr, which equates to a gas velocity of 20 feet per second (feet/sec) through the combustion chamber and an overall gas residence time of 2.2 seconds in the combustion system.

The following sections describe the feed system, combustion system, ash handling system, and air pollution control system. The discussion reference equipment is presented in Chapters 7.0 and 8.0.

6.2 Feed System

The CBC unit has three separate feed streams: limestone, Al_2O_3, and red water. These streams are shown in Drawing D-00-10-001 in Chapter 7.0.

6.2.1 Limestone

The limestone, in the form of granules and chunks, is fed into the CBC above the main mass of the circulating bed. The bags of limestone are elevated to the feed platform by a rail

mounted hoist (H-2006). The bags are broken with a bag breaker (H-2007) allowing the limestone to flow into the limestone feed hopper (H-2002). The limestone is metered out of the hopper and into the CBC via a variable speed screw conveyor (H-2003).

The flow of limestone to the CBC is manually controlled. The rate of limestone can be increased or decreased by adjusting the local speed controller SC-201 on screw conveyor H-2003. Before being installed, the limestone screw conveyor should be calibrated (using limestone) to determine the limestone flow rate versus the speed controller setting. This will allow the operator to estimate the limestone usage rate during operation of the CBC.

The limestone usage rate will be determined by feeding red water to the CBC and measuring SO_2 and HCl emissions in the flue gas. Limestone can then be added to the CBC bed to achieve the desired acid gas concentrations. This will accomplish two things; 1) it will define the correct limestone addition rate as a function of the red water feed rate, and 2) determine the efficiency and utilization of limestone for scrubbing acid gases in a CBC combustor. Both of these data points will be important for future system scale-up design. Note that the ratio of limestone versus red water feed rate is an approximation and is specific to the red water fed during acid gases testing. Changes in the red water composition may require increasing or decreasing the limestone feed rate.

6.2.2 Aluminum Oxide (Al_2O_3)

The Al_2O_3 consists of particles with a diameter of approximately 0.03 inch. The bags of Al_2O_3 are elevated by the hoist (H-2006) to the loop-seal platform. The bags are manually removed from the hoist and broken on the bag breaker (H-2008). The Al_2O_3 then flows into the feed hopper (H-2004). The Al_2O_3 feed screw conveyor (H-2005) is a variable speed type which transfers the Al_2O_3 from the hopper into the loop-seal. This loop-seal feed location is directly beneath the cyclone cone discharge.

The flow of Al_2O_3 to the CBC is manually controlled. The rate of Al_2O_3 can be increased or decreased by adjusting the local speed controller SC-202 on screw conveyor H-2005. As discussed above for the limestone screw conveyor, the Al_2O_3 screw conveyor should be

calibrated (using Al_2O_3) to determine the Al_2O_3 flow rate versus the speed controller setting. This will allow the operator to estimate the Al_2O_3 usage rate during operation of the CBC.

A differential pressure of 20 to 45 inches water column (in. w.c.) will be maintained across the bed. This pressure drop is an indication of the amount of bed material inside the CBC. The pressure drop across the chamber is measured by the pressure differential indicating transmitter PDIT-206 and is indicated by PDI-206.

The differential pressure across the circulating bed is controlled by both adding Al_2O_3 and withdrawing the bed material through the ash system. As salts build up in the CBC, the bed material must be taken out to keep the salt concentration at minimum level. The rate at which bed material is withdrawn will depend on the red water composition and operating experience. As the bed material is taken out, Al_2O_3 is added to the CBC until the desired differential pressure across the circulating bed is reached. The operator should also view the circulating behavior of the bed material through the sight ports. Again, through operating experience with the red water, salts buildup, and visual bed inspections, the operator will determine the proper Al_2O_3 feed rate to maintain the CBC differential pressure.

6.2.3 Red Water

The red water feed is fed into the loop-seal through a nozzle which is mounted on the Al_2O_3 inlet feed line from feed screw conveyor H-2005 to the loop-seal. The red water mixes with the aluminum oxide and then enters the loop-seal coming into contact with the circulating bed material.

All of the waste feed permissive interlocks must be satisfied before the red water block valve YV-205 can be opened. The flow of red water is measured by the flow meter and transmitter FE/FIT-205. Flow controller FIC-205 modulates the red water flow valve FV-205 to reach the desired flow rate.

When the CBC is ready to accept red water, the oxygen concentration at the stack is typically 10 to 12 percent, dry volume. This is due to the high rate of secondary air to the CBC in order to maintain the desired CBC off-gas flow rate (or velocity) for bed circulation. When

the red water is added to the CBC, the natural gas firing rate will increase thereby increasing CBC off-gas flow rate. In response to the increased CBC off-gas flow rate, the secondary air flow rate will decrease in order to maintain the desired, fixed CBC off-gas flow rate. Lowering the secondary air rate also lowers the stack oxygen concentration. In effect, increasing the red water feed rate will decrease the stack oxygen concentration. Therefore, the flow of red water to the CBC can be increased until the design red water rate is reached or the stack oxygen concentration decreases to about 6 percent, which ever comes first.

6.3 Combustion System

The combustion system comprises five regions: the wind box/distributor assembly, combustion chamber, bed, hot cyclone, and loop-seal. The system functions are described in the following sections.

6.3.1 Wind Box/Distributor Assembly

Located in the lower portion of the CBC, the wind box is made of refractory-lined carbon steel. The wind box receives combustion and circulating (secondary) air from the combustion air blower (B-2001). Under normal operating conditions, air at ambient temperature is blown into the wind box to serve as combustion air and circulating air. Under start-up conditions, the air is heated by the start-up burner (G-2001). The start-up burner is a 5 MMBtu/hr Vortex burner, which is located in the wind box. The primary combustion air is supplied at the burner and the secondary air enters the burner housing. The system will be heated by the start-up burner off-gases during start-up and hot idle. During start-up, the system is slowly heated to 1300°F. When the system attains 1300°F, the system slowly transfers to the primary fuel for normal operation. When there is no waste feed, the CBC system is placed on hot idle at 600°F to prevent the system from completely cooling down.

At the top of the wind box, a Hastelloy distributor plate with tuyeres is used to equalize air flow up through the bed region. During normal operation natural gas will bleed through tuyeres to combust and maintain temperature. The natural gas flow will begin flowing to the tuyeres after the start-up burner has brought the system up to 1300°F. At this temperature, the fuel will spontaneously combust when it enters the bottom of the combustion chamber. The fuel flow to the tuyeres is controlled as a function of the CBC the temperature.

6.3.2 Combustion Chamber

The combustion chamber located just above the distributor plate is a vertical cylindrical chamber made of refractory-lined carbon steel. The chamber has a 28-inch inside diameter and a 40.5-inch outside diameter. The carbon steel shell is 0.25 inch thick and is lined with 6 inches of castable refractory. The chamber has a height of 34 feet from the distributor plate to the top of the combustor and 4 feet from the distributor plate to the bottom of the wind box.

Turbulence, adequate residence time, and oxygen concentration in the gas at the required incineration temperature are essential for complete destruction of the nitrobodies. The gas velocity through the CBC unit is maintained at 20 feet/sec, which provides more than adequate turbulence. An approximate gas residence time of 2.2 seconds is maintained in the combustion module, which includes 1.7 seconds in the upper section of the CBC unit, 0.1 second in the duct between the CBC and the cyclone, 0.3 second in the cyclone, and 0.1 second in the duct between the cyclone and the partial quench. The combustion chamber temperature is maintained at approximately 1600°F, which is adequate for the destruction of the nitrobodies or any other organic compounds based on IT's experience. The cyclone exit off-gas contains about 6 percent oxygen (by volume), which is needed to achieve the required destruction. An oxygen content of 6 percent can be maintained based on IT's experience in operating CBCs.

6.3.3 Bed

Located above the wind box assembly, the bed comprises circulating media, which act as a large thermal flywheel for efficient heat transfer to the high moisture red water waste streams. Normal operating temperature in the CBC is 1600°F. The red water is pumped into the loop-seal, which returns bed media from the bottom of the cyclone to the bottom of the CBC.

The circulating bed consists of 64 percent Al_2O_3 and 36 percent limestone. The Al_2O_3 will be used to prevent agglomeration that could be caused by the high levels of sodium in the red water feed (Chapter 3.0). The limestone will be used to neutralize HCl and SO_2 in the combustion gas.

6.3.4 Hot Cyclone

The CBC off-gas will enter the hot cyclone (F-2002). The cyclone is made of refractory-lined carbon steel with a Hastelloy Vortex finder. The shell is 0.25 inch thick with 6 inches of castable refractory, with an outside diameter of 38 inches and a length of 120 inches. The cyclone is designed to remove the circulating media that have been carried over from the CBC by use of centrifugal forces to separate the heavier particles from the off-gas. The separated particles then flow out of the bottom of the cyclone, into the loop seal, and then back into the CBC bed.

6.3.5 Loop-Seal

The circulating media removed from the combustion off-gas are returned to the bed through a loop-seal. The loop-seal is a refractory-lined carbon steel duct that connects from the bottom of the cyclone cone to the CBC. The loop-seal has a 3-inch inside diameter and a 15-inch outside diameter. The make-up circulating media (aluminum oxide) are added to the loop-seal through a screw conveyor (H-2005), which are fed by a hopper (H-2004). Purge air is injected into the loop-seal by the purge air blower (B-2002) and maintains the circulating media in a fluidized state. The red water waste feed is injected into the circulating media inlet line.

6.3.6 Combustion System Process Control Description

During the start-up of the CBC, the start-up burner slowly heats the system to ensure even refractory heatup. During this start-up, the temperature is measured by thermocouples TE-207A and TE-207B in the wind box. This temperature is controlled by temperature indicating controller TIC-207 which sets the fuel flow rate to the start-up burner by cascading the temperature requirement to the fuel flow indicating controller FIC-209. FIC-209 modulates the fuel valve FV-209 until the flow demand is satisfied.

Primary combustion air is supplied to the start-up burner for stoichiometric combustion of any fuel fired. The primary combustion air is controlled by the ratio controller FFIC-204 which receives a set point from the fuel flow indicating transmitter (FIT-209). FFIC-204 adjusts the primary air flow valve (FV-204) according to the set ratio.

The normal operating temperature in the CBC is measured by thermocouples TE-206A and 206B. This temperature is controlled by a temperature indicating controller (TIC-206). TIC-206 sets the fuel flow to the tuyeres by cascading the temperature requirement to the fuel flow indicating controller FIC-219. FIC-219 modulates flow valve FV-219 until the flow demand is achieved.

Maintaining the CBC off-gas flow rate to obtain a velocity between 15 to 20 ft/sec is required in order to continuously circulate the bed material. The CBC off-gas flow rate (or velocity) is maintained by adjusting the flow of secondary air to the CBC. The CBC calculated off-gas flow rate is indicated by flow indicating controller FIC-201. FIC-201 modulates the secondary air flow valve FV-201 until the desired CBC off-gas flow is obtained.

The CBC vacuum is maintained by modulating the I.D. Fan inlet vane damper PV-501. The CBC vacuum is measured by pressure transmitter PIT-210 and is located on the loop seal. The pressure indicating controller PIC-210 varies the position of PV-501 in order to maintain the desired vacuum set point.

6.4 Ash Handling

The ash and the circulating media are continuously removed by the ash cooler conveyor (H-2001). The ash cooler conveyor is a variable speed, water-jacketed screw conveyor made of carbon steel, with a 5-horsepower (hp) drive motor. The ash cooler conveyor extracts the ash/circulating media from the bottom portion of the bed. The ash/circulating media are transferred through the screw conveyor, where it is cooled to about 600°F and then dropped into the ash bin (T-2001). The ash/used circulating media are transferred from the bin to storage or disposal.

The ash cooler conveyor will be controlled manually. Based on operating experience in other CBCs, the flow rate is adjusted based on maintaining 2 percent salt in the bed.

6.5 Air Pollution Control System

The APCS consists of a partial quench, baghouse, I.D. fan, and a stack.

6.5.1 Partial Quench. Incinerator off-gas from the CBC is routed to the partial quench spray chamber (T-5001) through a refractory-lined duct. The partial quench reduces the temperature from 1600°F to an operating temperature of 400°F (450°F maximum). The size of the carbon steel quench chamber is 40 inches outside diameter and 33 feet in length, with a 3-second gas residence time. The dry-bottom quench chamber is equipped with two atomizing nozzles for introducing cooling water. An airtight motor-driven rotary valve (H-5001) is used to discharge collected dust to the dust collection drum (T-5002A). The quench chamber is constructed of painted carbon steel.

Quench temperature is measured by a thermocouple (TE-501) at the quench chamber outlet. This temperature is controlled by a temperature indicating controller (TIC-501) that sets the water flow to the quench chamber by controlling the flow valve (TV-501) in accordance with the water demand. The partial quench has two water sources with one for normal operation and the other for emergencies only.

6.5.2 Baghouse

Quenched off-gas will be routed from the quench chamber to the baghouse (S-5001). The four-module baghouse has dimensions of 13 by 17 feet with a 26-foot overall height (including supports). The baghouse has an air-to-cloth ratio of 3:1. It will have a bottom with sides sloped at a 60-degree horizontal angle and will be equipped with a vibrating bottom. An airtight, motor-driven rotary valve (H-5002) will be used to discharge dust from the bag filter to the dust collection drum (T-5002B). The baghouse body will be constructed of 0.5-inch steel lined with 2 inches of insulation. An on-line pulse-jet type cleaning mechanism will be included in the bag filter to automatically remove collected dust from the bags. The bags will be precoated with lime to prevent the bags from clogging and to react with any fugitive SO_2 or HCl that may be in the quench off-gas.

A key issue that should be considered during the process/detail engineering phase of this project is transportability. One objective is that the entire unit be mobile/transportable; the proposed baghouse is based on a conventional design with relatively lengthy bags that make the unit taller. During the detail engineering phase, a shorter baghouse design should be considered for mobility.

Due to the high-pressure drop across the system, the I.D. fan is specified to produce 60 in. w.c. static pressure. The infiltration air through the rotary valves in each of the four modules could be significant. To minimize the infiltration air into the system, a solenoid-operated knife gate valve is installed upstream of the rotary valve(s).

Pressure drop across the baghouse is measured by a pressure differential-indicating transmitter (PDIT-504). The differential pressure measurement is used to control the cycle initiation for the pulse-jet type cleaning mechanism. Configured from PDIT-504 is the pressure differential indicator (PDI-504) and high differential pressure switch PDSH-504. When the differential pressure exceeds the set point of PDSH-504, the bags are air pulsed for cleaning.

6.5.3 Induced Draft Fan

The prime mover of the CBC system is the I.D. fan (B-5001). The fan draws gas from the baghouse exit. The flow rate is set by an inlet vane damper (PV-501) in the duct before the I.D. fan. The inlet damper is an electrically actuated damper that is controlled to maintain the CBC pressure at a desired vacuum. The I.D. fan is a centrifugal type blower with a capacity of 5,000 acfm and a static pressure of 60 in. w.c.

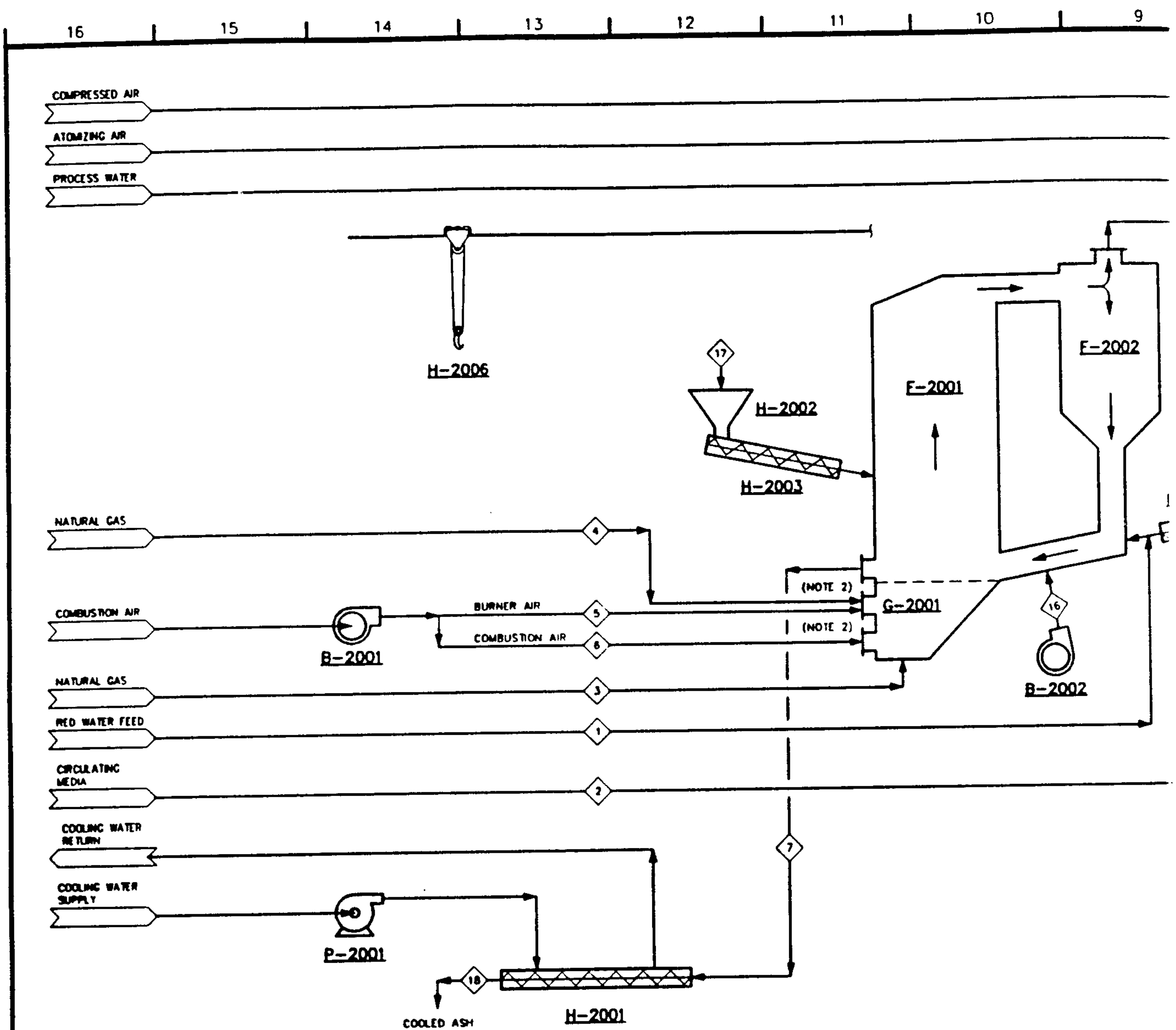
6.5.4 Stack

The I.D. fan discharges flue gas through the stack (Z-5001). The stack is 12 inches in diameter with a 62-foot height. The stack height of 62 feet is based on housing the entire system in a building 50 feet high. If the system is installed in an open area, the minimum stack height should be 45 feet. The stack is equipped with a continuous emission monitoring (CEM) system for oxygen (O_2) and CO. The NO_x and SO_x is measured during the performance testing. The CEM system includes alarm points in the control system for all of the above parameters. The stack is also equipped with nozzles and platforms necessary to allow sampling during the performance test.

7.0 PFD AND P&IDs PACKAGE

7.0 PFDs & P&IDs (Revision A) Drawing Index

Type	Title	Area Number	Drawing Number
PFD	Incineration System	00	D-00-10-001
P&ID	Instrumentation Identification	00	D-00-11-001
P&ID	Control System Standards	00	D-00-11-002
P&ID	Control Loop Standards	00	D-00-11-003
P&ID	Equipment Identification	00	D-00-11-004
P&ID	CBC Burner System	20	D-20-11-001
P&ID	Circulating Bed Combustor	20	D-20-11-002
P&ID	APC System	50	D-50-11-001



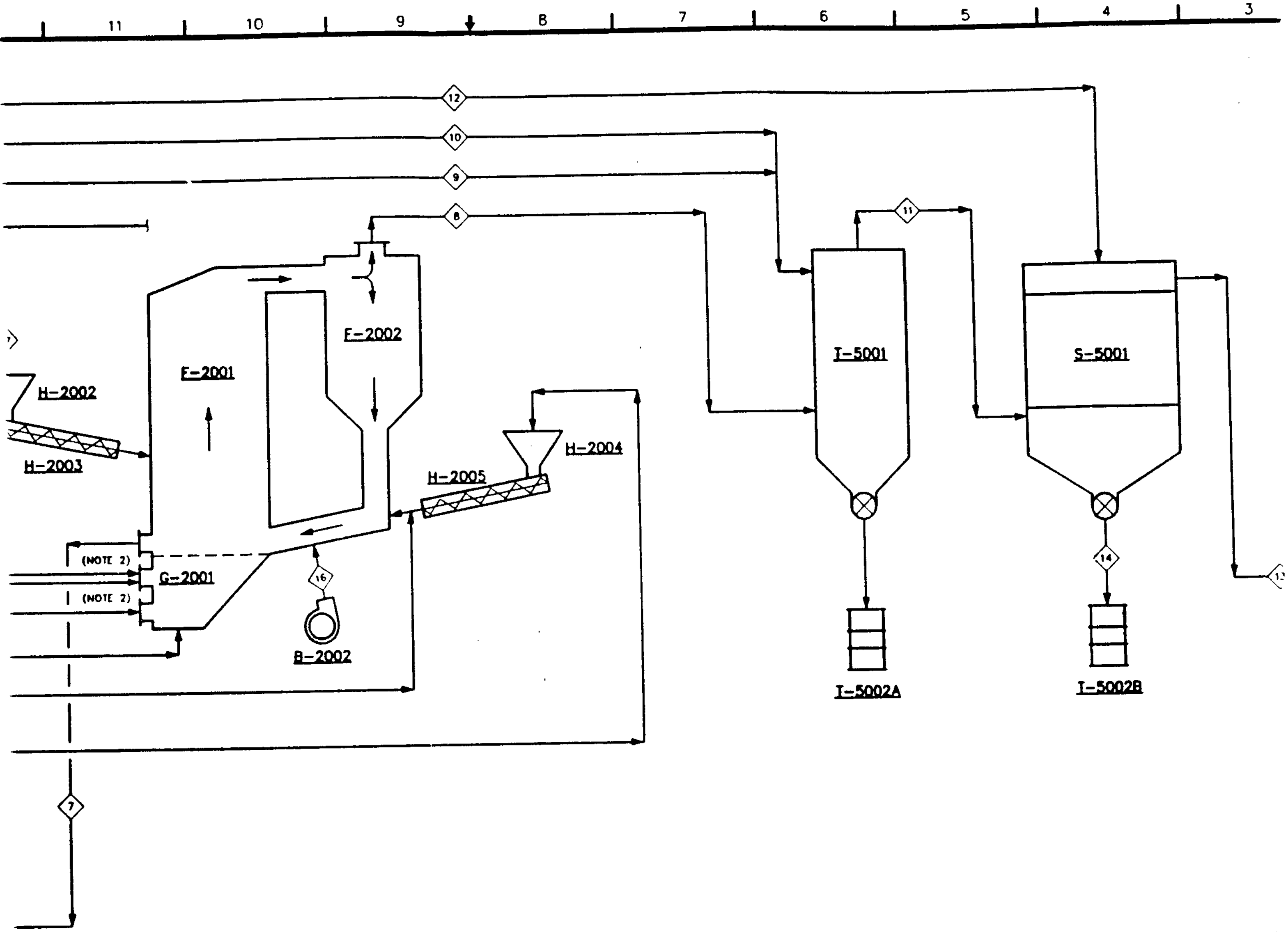
H-2006	B-2001	P-2001	H-2002	H-2003	F-2001	G-2001	H-1001
HOIST	COMBUSTION AIR BLOWER	COOLING WATER RECIRC. PUMP	LIMESTONE FEED HOPPER	LIMESTONE FEED CONVEYOR	CIRCULATING BED COMBUSTOR (CBC)	START-UP BURNER	ASH COOLER CONVEYOR

32224301 12/07/94 2:57pm JMH

STREAM NO.		1	2	3	4	5	6	7	8	9	10	1
COMPONENT		RED WATER FEED	ALUMINUM OXIDE	NATURAL GAS	START-UP GAS	START-UP AIR	COMBUSTION AIR	ASH	CYCLONE OFF-GAS	QUENCH WATER	ATOMIZATION AIR	PAR QUE OFF-
CO_2	LB/HR								584			
CO	LB/HR								0.037			0
O_2	LB/HR						982		219		178	
N_2	LB/HR						3252		3261		589	
H_2O (VAPOR)	LB/HR	702	(NOTE 3)		(NOTE 4)	(NOTE 4)			1150		(7 75)	
SALTS	LB/HR								59			
DISSOLVED SOLIDS	LB/HR	124										
TOTAL MASS FLOW	LB/HR	826	43.5	182			4234	70	5284	1551	775	
TOTAL VOLUMETRIC FLOW	(SCFM) (ACFM) GPM	1.5					(928)		(5027)	3.1	(170)	(3
TEMPERATURE	°F	60	60	60			60	1600	1600	60	60	
PRESSURE	PSIG (in. w.c. abs.)					30	30		405			
ENTHALPY	MMBTU/HR	0.4		4					3.8			

NOTES

1. ALL THE VALUES IN THE PFD ARE FOR NORMAL OPERATION.
2. START-UP USAGE ONLY.
3. ADDED AT A RATE WHERE THE DIFFERENTIAL PRESSURE ACROSS THE COMBUSTOR WILL NOT DROP BELOW 30" H_2O
4. START-UP SUPPLY ONLY
5. INTERMITTANT AIR FLOW



)3 ...E ...NVEYOR

E-2001 CIRCULATING BED COMBUSTOR (CBC)

G-2001 START-UP BURNER

H-1001 ASH COOLER CONVEYOR

E-2002 CYCLONE SEPARATOR

H-2004 Al_2O_3 FEED

H-2005 Al_2O_3 FEED CONVEYOR

B-2002 LOOP-SEAL PURGE AIR BLOWER

I-5001 PARTIAL QUENCH

S-5001 BAGHOUSE

I-5002A,B DUST COLLECTION DRUMS

5	6	7	8	9	10	11	12	13	14	15	16	17	18					
...RT-UP AIR	COMBUSTION AIR	ASH	CYCLONE OFF-GAS	QUENCH WATER	ATOMIZATION AIR	PARTIAL QUENCH OFF-GAS	BAGHOUSE PULSE AIR	BAGHOUSE OFF-GAS	BAGHOUSE DUST	STACK OFF-GAS	PURGE AIR	LIMESTONE	COOLED ASH					
			584			584		584		584								
			0.037			0.037		0.037		0 037								
	982		219		178	397		397		397								
	3252		3261		589	3851		3851		3851								
...TE 4)			1150		(7 75)	2707	(NOTE 5)	2707		2707		(NOTE 3)						
			59			59		0 6		0.6								
	4234	70	5284	1551	775	7609		7550	58 5	7550		28.8	70					
	[928]		(5027)	3 1	[170]	(3439)		(3617)		(3443)	[100]							
	60	1600	1600	60	60	459		439	439	415	60	60	600					
30	30		405			404		384		406 8								
			3 8			3.8		3 8										

NO.	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR
A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	JWH	SM	PA	PA	PA	

STARTING DATE 8/26/94 | INITIATOR PA / CHKD PA | DRAWN JWH / CHKD PA | PROJECT MGR P. ACHARYA

INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

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PROJ...

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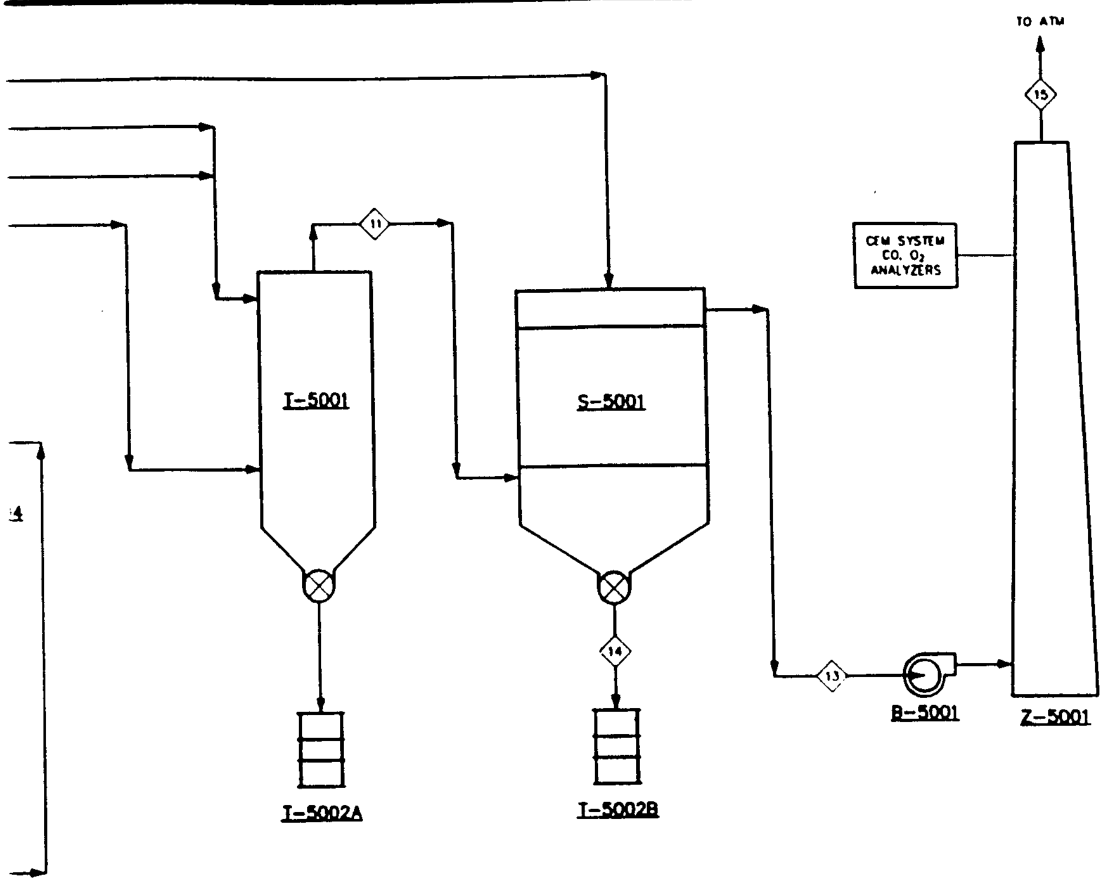

I-2004	H-2005	B-2002	I-5001	S-5001	I-5002A,B	B-5001	Z-5001
Al_2O_3 FEED	Al_2O_3 FEED CONVEYOR	LOOP-SEAL PURGE AIR BLOWER	PARTIAL QUENCH	BAGHOUSE	DUST COLLECTION DRUMS	INDUCED DRAFT FAN	STACK

14	15	16	17	18
BAGHOUSE DUST	STACK OFF-GAS	PURGE AIR	LIMESTONE	COOLED ASH
	584			
	0 037			
	397			
	3851			
	2707		(NOTE 3)	
	0.6			
58 5	7550		28.8	70
	(3443)	100		
439	415	60	60	600
	406 8			

3

TO USAEC	JMH	SM	PA	PA	PA	
	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR

PA | DRAWN JMH / CHKD PA | PROJECT MGR P. ACHARYA

INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

PROCESS FLOW DIAGRAM
INCINERATION SYSTEM

PROJ. NO.	DRAWING NO.	REV
322243	D-00-10-001	A

16	15	14	13	12	11	10	9

	IDENTIFICATION LETTERS					
	FIRST-LETTER (4)		SUCCEEDING-LETTERS (3)			
SYMBOL	MEASURED OR INITIATING VARIABLE	MODIFIER	READOUT, OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER	RECORDIN
A	ANALYSIS (5,19)		ALARM			ARC
B	BURNER, COMBUSTION		USER'S CHOICE (1)	USER'S CHOICE (1)	USER'S CHOICE (1)	BRC
C	CONDUCTIVITY			CONTROL (13)		
D	DENSITY OR S.G.	DIFFERENTIAL (4)				
E	VOLTAGE		SENSOR (PRIMARY ELEMENT)			ERC
F	FLOW RATE	RATIO (FRACTION) (4)				FRC FQRC FFRC
G	USER'S CHOICE (1)		GLASS, VIEWING DEVICE (9)			
H	HAND				HIGH (7,15,16)	
I	CURRENT (ELECTRICAL)		INDICATE (10)			IRC
J	POWER	SCAN (7)				JRC
K	TIME, TIME SCHEDULE	TIME, TIME RATE OF CHANGE (4,21)		CONTROL STATION (22)		KRC
L	LEVEL		LIGHT (11)		LOW (7,15,16)	LRC
M	MOISTURE/HUMIDITY	MOMENTARY (4)			MIDDLE, INTERMEDIATE (7,15)	
N	CLOSED CIRCUIT TV (CCTV)		USER'S CHOICE (1)	USER'S CHOICE (1)	USER'S CHOICE (1)	
O	USER'S CHOICE (1)		ORIFICE, RESTRICTION			
P	PRESSURE, VACUUM		POINT (TEST) CONNECTION (23)			PRC PDRC
Q	QUANTITY	INTEGRATE, TOTALIZE (4)				QRC
R	RADIATION		RECORD (17)			RRC
S	SPEED, FREQUENCY	SAFETY (8)		SWITCH (13)		SRC
T	TEMPERATURE			TRANSMIT (18)		TRC TDRC
• U	MULTIVARIABLES (6)		MULTIFUNCTION (12)	MULTIFUNCTION (12)	MULTIFUNCTION (12)	
V	VIBRATION MECHANICAL ANALYSIS (19)			VALVE, DAMPER, LOUVER (13,24)		
W	WEIGHT, FORCE		WELL			WRC WDRC
X	UNCLASSIFIED (2)	X AXIS	UNCLASSIFIED (2)	UNCLASSIFIED (2)	UNCLASSIFIED (2)	
Y	EVENT, STATE OR PRESENSE (20)	Y AXIS		RELAY, COMPUTE, CONVERT (13,14,18)		
Z	POSITION, DIMENSION	Z AXIS		DRIVER, ACTUATOR,UNCLASSIFIED FINAL CONTROL ELEMENT		ZRC ZDRC

INSTRUMENT IDENTIFICATION

NOTES FOR TABLE

NOTE.

- • THIS TABLE IS NOT ALL-INCLUSIVE.
- •• A ALARM, THE ANNUNCIATING DEVICE MAY BE USED IN THE SAME FASHION AS S SWITCH THE ACTUATING DEVICE.
- ••• THE LETTERS H AND L MAY BE OMITTED IN THE UNDERFINED CASE.

OTHER POSSIBLE COMBINATIONS

FO	(RESTRICTION ORIFICE)
FRK, HIK	(CONTROL STATIONS)
FX	(ACCESSORIES)
TJR	SCANNING RECORDER)
LLH	(PILOT LIGHT)
PFR	(RATIO)
KQI	(RUNNING TIME INDICATOR)
QQI	(INDICATING COUNTER)
WKIC	(RATE-OF-WEIGHT-LOSS CONTROLLER)
HMS	(HAND MOMENTARY SWITCH)

1. A "USER'S CHOICE" LETTER IS INTENDED TO COVER UNLISTED MEANINGS THAT WILL BE USED REPETITIVELY IN A PARTICULAR PROJECT. IF USED, THE MAY LETTER MAY HAVE ONE MEANING AS A FIRST-LETTER AND ANOTHER MEANING AS A SUCCEEDING-LETTER. THE MEANINGS NEED TO BE DEFINED ONLY ONCE IN A LEGEND, OR OTHER PLACE, FOR THAT PROJECT. FOR EXAMPLE, THE LETTER N MAY BE DEFINED AS "MODULUS OF ELASCITY" AS A FIRST-LETTER AND "OSCILLOSCOPE" AS A SUCCEEDING-LETTER.

2. THE UNCLASSIFIED LETTER X IS INTENDED TO COVER UNLISTED MEANINGS THAT WILL BE USED ONLY ONCE OR USED TO A LIMITED EXTENT. IF USED, THE LETTER MAY HAVE ANY NUMBER OF MEANINGS AS A FIRST-LETTER AND ANY NUMBER OF MEANINGS AS A SUCCEEDING LETTER, EXCEPT FOR ITS USE WITH DISTINCTIVE SYMBOLS. IT IS EXPECTED THAT THE MEANINGS WILL BE DEFINED OUTSIDE A TAGGING BUBBLE ON A FLOW DIAGRAM. FOR EXAMPLE, XR-2 MAY BE A STRESS RECORDER AND XX-4 MAY BE A STRESS OSCILLOSCOPE

3. THE GRAMMATICAL FORM OF THE SUCCEEDING-LETTER MEANINGS MAY BE MODIFIED AS REQUIRED. FOR EXAMPLE, "INDICATE" MAY BE APPLIED AS "INDICATOR" OR "INDICATING". "TRANSMIT" AS "TRANSMITTER" OR "TRANSMITTING", ETC

4. ANY FIRST-LETTER, IF USED IN COMBINATION WITH MODIFYING LETTERS D(DIFFERENTIAL), F(RATIO), M(MOMENTARY), K(TIME OF CHANGE), Q(INTEGRATE OR TOTALIZE), OR ANY COMBINATION OF THESE IS INTENDED TO REPRESENT A NEW AND SEPARATE MEASURED VARIABLE, AND THE COMBINATION IS TREATED AS A FIRST-LETTER ENTITY. THUS, INSTRUMENTS TDI AND TI INDICATE TWO DIFFERENT VARIABLES. NAMELY, DIFFERENTIAL-TEMPERATURE AND TEMPERATURE. MODIFYING LETTERS ARE USED AS APPLICABLE.

5. FIRST-LETTER A(ANALYSIS) COVERS ALL ANALYSES NOT DESCRIBED BY A "USER'S CHOICE" LETTER. IT IS EXPECTED THAT THE TYPE OF ANALYSIS WILL BE DEFINED OUTSIDE A TAGGING BUBBLE. SOME EXAMPLES ARE:

CO	-CARBON MONOXIDE	O	-DISSOLVED OXYGEN
COMB	-COMBUSTIBLES	O2	-GASEOUS OXYGEN
H	-DISSOLVED HYDROGEN	pH	-pH
H2	-GASEOUS HYDROGEN	CL2	-GASEOUS CHLORINE
Na	-SODIUM	SMOKE	-SMOKE DENSITY
N2H4	-HYDRAZINE	SO2	-SULPHUR DIOXIDE
NOx	-NITROGEN OXIDES	TRB	-TURBIDITY

6. USE A FIRST-LETTER U FOR "MULTIVARIABLE" IN LIEU OF A COMBINATION OF FIRST-LETTERS IS OPTIONAL. IT IS RECOMMENDED THAT NONSPECIFIC VARIABLE DESIGNATORS SUCH AS U BE USED SPARINGLY.

7. THE USE OF MODIFYING TERMS "HIGH", "LOW", "MIDDLE", OR "INTERMEDIATE", AND "SCAN" IS OPTIONAL.

8. THE TERM "SAFETY" APPLIES TO EMERGENCY PROTECTIVE PRIMARY ELEMENTS AND EMERGENCY PROTECTIVE FINAL CONTROL ELEMENTS ONLY. THUS, A SELF-ACTUATED VALVE THAT PREVENTS OPERATION OF A FLUID SYSTEM AT A HIGHER-THAN-DESIRED PRESSURE BY BLEEDING FLUID FROM THE SYSTEM IS A BACK-PRESSURE-TYPE PCV, EVEN IF THE VALVE IS NOT INTENDED TO BE USED NORMALLY. HOWEVER, THIS VALVE IS DESIGNATED AS A PSV IF IT IS INTENDED TO PROTECT AGAINST EMERGENCY CONDITIONS I.E. CONDITIONS THAT ARE HAZARDOUS TO PERSONNEL AND/OR EQUIPMENT AND THAT ARE NOT EXPECTED TO ARISE NORMALLY.

9. THE PASSIVE FUNCTION G APPLIES TO INSTRUMENTS OR DEVICES THAT PROVIDE AN UNCALIBRATED VIEW, SUCH AS SIGHT GLASSES AND TELEVISION MONITORS

10. "INDICATE" NORMALLY APPLIES TO THE READOUT-ANALOG OR DIGITAL-OF AN ACTUAL MEASUREMENT. IN THE CASE OF A MANUAL LOADER, IT MAY BE USED FOR THE DIAL OR SETTING INDICATION, I.E., FOR THE VALUE OF THE INITIATING VARIABLE

11. A PILOT LIGHT THAT IS PART OF AN INSTRUMENT LOOP SHOULD BE DESIGNATED BY A FIRST-LETTER FOLLOWED BY THE SUCCEEDING-LETTER L. FOR EXAMPLE, A PILOT LIGHT THAT INDICATES AN EXPIRED TIME PERIOD SHOULD BE TAGGED KQL. IF IT IS DESIRED TO TAG A PILOT LIGHT THAT IS NOT PART OF AN INSTRUMENT LOOP, THE LIGHT IS DESIGNATED IN THE SAME WAY. FOR EXAMPLE, A RUNNING LIGHT FOR AN ELECTRIC MOTOR MAY BE TAGGED EL, ASSUMING VOLTAGE TO BE THE APPROPRIATE MEASURED VARIABLE, OR YL, ASSUMING THE OPERATING STATUS IS BEING MONITORED. THE UNCLASSIFIED VARIABLE X SHOULD BE USED ONLY FOR APPLICATIONS WHICH ARE LIMITED IN EXTENT. THE DESIGNATION XL SHOULD NOT BE USED FOR MOTOR RUNNING LIGHTS, AS THESE ARE COMMONLY NUMEROUS. IT IS PERMISSIBLE TO USE THE USER'S CHOICE LETTERS M,N OR O FOR A MOTOR RUNNING LIGHT WHEN THE MEANING IS PREVIOUSLY DEFINED. IF M IS USED, IT MUST BE CLEAR THAT THE LETTER DOES NOT STAND FOR THE WORD "MOTOR", BUT FOR A MONITORED STATE.

12. USE OF A SUCCEEDING-LETTER U FOR "MULTIFUNCTION" INSTEAD OF A COMBINATION OF OTHER FUNCTIONAL LETTERS IS OPTIONAL. THIS NONSPECIFIC FUNCTION DESIGNATOR SHOULD BE USED SPARINGLY.

13. A DEVICE THAT CONNECTS, DISCONNECTS, OR TRANSFERS ONE OR MORE CIRCUITS MAY BE EITHER A SWITCH, A RELAY, AN ON-OFF CONTROLLER, OR A CONTROL VALVE, DEPENDING ON THE APPLICATION.

IF THE DEVICE MANIPULATES A FLUID PROCESS ST[…] NOT A HAND-ACTUATED ON-OFF BLOCK VALVE IT […] AS A CONTROL VALVE. IT IS INCORRECT TO USE T[…] SUCCEEDING-LETTERS CV FOR ANYTHING OTHER TH[…] ACTUATED CONTROL VALVE. FOR ALL APPLICATIONS […] FLUID PROCESS STREAMS. THE DEVICE IS DESIGNA[…] FOLLWS.

A SWITCH, IF IT IS ACTIVATED BY HAND

A SWITCH OR AN ON-OFF CONTROLLER. IF IT I[…] AUTOMATIC AND IS THE FIRST SUCH DEVICE IN […] LOOP. THE TERM "SWITCH" IS GENERALLY USED […] IF THE DEVICE IS USED FOR ALARM, PILOT LIGH[…] SELECTION, INTERLOCK, OR SAFETY.

THE TERM "CONTROLLER" IS GENERALLY USED I[…] THE DEVICE IS USED FOR NORMAL OPERATING […]

A RELAY, IF IT IS AUTOMATIC AND IS NOT THE […] SUCH DEVICE IN A LOOP, I.E., IT IS ACTUATED […] A SWITCH OR AN ON-OFF CONTROLLER

14. IT IS EXPECTED THAT THE FUNCTIONS ASSOCIATED […] OF SUCCEEDING-LETTER Y WILL BE DEFINED OUTS[…] ON A DIAGRAM WHEN FURTHER DEFINITION IS CONS[…] NECESSARY. THIS DEFINITION NEED NOT BE MADE […] FUNCTION IS SELF-EVIDENT. AS FOR A SOLENOID V[…] FLUID SIGNAL LINE

15. THE MODIFYING TERMS "HIGH" AND "LOW" AND "MI[…] "INTERMEDIATE" CORRESPOND TO VALUES OF THE […] VARIABLE, NOT TO VALUES OF THE SIGNAL, UNLES[…] NOTED. FOR EXAMPLE, A HIGH-LEVEL ALARM DERIV[…] A REVERSE-ACTING LEVEL TRANSMITTER SIGNAL SH[…] LAH, EVEN THOUGH THE ALARM IS ACTUATED WHEN […] FALLS TO A LOW VALUE. THE TERMS MAY BE USE[…] COMBINATION AS APPROPRIATE.

16. THE TERMS "HIGH" AND "LOW" WHEN APPLIED TO […] VALUES AND OTHER OPEN-CLOSE DEVICES, ARE D[…] FOLLOWS: "HIGH" DENOTES THAT THE VALVE IS IN […] APPROACHING THE FULLY OPEN POSITION, AND "LO[…] THAT IT IS IN OR APPROACHING THE FULLY CLOSE[…]

17. THE WORD "RECORD" APPLIES TO ANY FORM OF P[…] STORAGE OF INFORMATION THAT PERMITS RETRIEVAL […] MEANS.

18. FOR USE OF THE TERM "TRANSMITTER" VERSUS "C[…] SEE DEFINITIONS IN SECTION 3 OF REFERENCE DO[…]

19. FIRST-LETTER V, "VIBRATION OR MECHANICAL ANAL[…] INTENDED TO PERFORM THE DUTIES IN MACHINERY […] THAT THE LETTER A PERFORMS IN MORE GENERAL […] EXCEPT FOR VIBRATION, IT IS EXPECTED THAT THE […] OF INTEREST WILL BE DEFINED OUTSIDE THE TAGGI[…]

20. FIRST-LETTER Y IS INTENDED FOR USE WHEN CON[…] MONITORING RESPONSES ARE EVENT-DRIVEN AS OP[…] TIME OR TIME SCHEDULE-DRIVEN. THE LETTER Y, I[…] POSITION, CAN ALSO SIGNIFY PRESENCE OR STATE […]

21. MODIFYING-LETTER K, IN COMBINATION WITH A FIRS[…] SUCH AS L, T, OR W, SIGNIFIES A TIME RATE OF […] THE MEASURED OR INITIATING VARIABLE. THE VARIA[…] FOR INSTANCE, MAY REPRESENT A RATE-OF-WEIGH[…] CONTROLLER.

NOTES

1 THE PURPOSE OF THIS SHEET IS TO PRESENT A BASIC DEFINITION OF THE SYSTEM USED FOR INSTRUMENT IDENTIFICATION. THIS SHEET SHOULD PROVIDE SUFFICIENT INFORMATION TO ALLOW MOST USERS TO UNDERSTAND THE INSTRUMENT REPRESENTATION USED ON THE ASSOCIATED P & IDS

A	10/13/94
NO	DATE
STARTING DATE	9/12

12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4

	SUCCEEDING-LETTERS (3)		TYPICAL LETTER COMBINATIONS *														
			CONTROLLERS				READOUT DEVICES		SWITCHES AND ALARM DEVICES **			TRANSMITTERS			SOLENOIDS, RELAYS, COMPUTING DEVICES	PRIM ELEM
	OUTPUT FUNCTION	MODIFIER	RECORDING	INDICATING	BLIND	SELF-ACTUATED CONTROL VALVES	RECORDING	INDICATING	HIGH***	LOW	COMB	RECORDING	INDICATING	BLIND		
			ARC	AIC	AC		AR	AI	ASH	ASL	ASHL	ART	AIT	AT	AY	AE
	USER'S CHOICE (1)	USER'S CHOICE (1)	BRC	BIC	BC		BR	BI	BSH	BSL	BSHL	BRT	BIT	BT	BY	BE
	CONTROL (13)															
ELEMENT)			ERC	EIC	EC		ER	EI	ESH	ESL	ESHL	ERT	EIT	ET	EY	EE
			FRC FQRC FFRC	FIC FQIC FFIC	FC FFC	FCV, FICV	FR FQR FFR	FI FQI FFI	FSH FQSH FFSH	FSL FQSL FFSL	FSHL	FRT	FIT FQIT	FT FQT	FY FQY	FE FQE FE
ICE (9)																
		HIGH (7,15,16)		HIC	HC						HS					
			IRC	IIC			IR	II	ISH	ISL	ISHL	IRT	IIT	IT	IY	IE
			JRC	JIC			JR	JI	JSH	JSL	JSHL	JRT	JIT	JT	JY	JE
	CONTROL STATION (22)		KRC	KIC	KC	KCV	KR	KI	KSH	KSL	KSHL	KRT	KIT	KT	KY	KE
		LOW (7,15,16)	LRC	LIC	LC	LCV	LR	LI	LSH	LSL	LSHL	LRT	LIT	LT	LY	LE
		MIDDLE, INTERMEDIATE (7,15)														
	USER'S CHOICE (1)	USER'S CHOICE (1)														
N																
CTION (23)			PRC PDRC	PIC PDIC	PC PDC	PCV PDCV	PR PDR	PI PDI	PSH PDSH	PSL PDSL	PSHL	PRT PDRT	PIT PDIT	PT PDT	PY PDY	PE PE
			QRC	QIC			QR	QI	QSH	QSL	QSHL	QRT	QIT	QT	QY	QE
			RRC	RIC	RC		RR	RI	RSH	RSL	RSHL	RRT	RIT	RT	RY	RE
	SWITCH (13)		SRC	SIC	SC	SCV	SR	SI	SSH	SSL	SSHL	SRT	SIT	ST	SY	SE
	TRANSMIT (18)		TRC TDRC	TIC TDIC	TC TDC	TCV TDCV	TR TDR	TI TDI	TSH TDSH	TSL TDSL	TSHL	TRT TDRT	TIT TDIT	TT TDT	TY TDY	TE TE
	MULTIFUNCTION (12)	MULTIFUNCTION (12)					UR	UI							UY	
	VALVE, DAMPER, LOUVER (13,24)						VR	VI	VSH	VSL	VSHL	VRT	VIT	VT	VY	VE
			WRC WDRC	WIC WDIC	WC WDC	WCV WDCV	WR WDR	WI WDI	WSH WDSH	WSL WDSL	WSHL	WRT WDRT	WIT WDIT	WT WDT	WY WDY	WE WE
	UNCLASSIFIED (2)	UNCLASSIFIED (2)														
	RELAY, COMPUTE, CONVERT (13,14,18)			YIC	YC		YR	YI	YSH	YSL				YT	YY	YE
	DRIVER, ACTUATOR, UNCLASSIFIED FINAL CONTROL ELEMENT		ZRC ZDRC	ZIC ZDIC	ZC ZDC	ZCV ZDCV	ZR ZDR	ZI ZDI	ZSH ZDSH	ZSL ZDSL	ZSHL	ZRT ZDRT	ZIT ZDIT	ZT ZDT	ZY ZDY	ZE ZDE

OVERS ALL ANALYSES NOT
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MPLES ARE.

DE	O	-DISSOLVED OXYGEN
	O2	-GASEOUS OXYGEN
OGEN	pH	-pH
GEN	CL2	-GASEOUS CHLORINE
	SMOKE	-SMOKE DENSITY
	SO2	-SULPHUR DIOXIDE
S	TRB	-TURBIDITY

"MULTIVARIABLE" IN LIEU OF A
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THE TERM "CONTROLLER" IS GENERALLY USED IF THE DEVICE IS USED FOR NORMAL OPERATING CONTROL

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14 IT IS EXPECTED THAT THE FUNCTIONS ASSOCIATED WITH THE USE OF SUCCEEDING-LETTER Y WILL BE DEFINED OUTSIDE A BUBBLE ON A DIAGRAM WHEN FURTHER DEFINITION IS CONSIDERED NECESSARY. THIS DEFINITION NEED NOT BE MADE WHEN THE FUNCTION IS SELF-EVIDENT. AS FOR A SOLENOID VALVE IN A FLUID SIGNAL LINE

15. THE MODIFYING TERMS "HIGH" AND "LOW" AND "MIDDLE" OR "INTERMEDIATE" CORRESPOND TO VALUES OF THE MEASURED VARIABLE. NOT TO VALUES OF THE SIGNAL, UNLESS OTHERWISE NOTED. FOR EXAMPLE, A HIGH-LEVEL ALARM DERIVED FROM A REVERSE-ACTING LEVEL TRANSMITTER SIGNAL SHOULD BE AN LAH, EVEN THOUGH THE ALARM IS ACTUATED WHEN THE SIGNAL FALLS TO A LOW VALUE THE TERMS MAY BE USED IN COMBINATION AS APPROPRIATE.

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17. THE WORD "RECORD" APPLIES TO ANY FORM OF PERMANENT STORAGE OF INFORMATION THAT PERMITS RETRIEVAL BY ANY MEANS.

18. FOR USE OF THE TERM "TRANSMITTER" VERSUS "CONVERTER", SEE DEFINITIONS IN SECTION 3 OF REFERENCE DOCUMENT.

19. FIRST-LETTER V, "VIBRATION OR MECHANICAL ANALYSIS", IS INTENDED TO PERFORM THE DUTIES IN MACHINERY MONITORING THAT THE LETTER A PERFORMS IN MORE GENERAL ANALYSES EXCEPT FOR VIBRATION, IT IS EXPECTED THAT THE VARIABLE OF INTEREST WILL BE DEFINED OUTSIDE THE TAGGING BUBBLE

20. FIRST-LETTER Y IS INTENDED FOR USE WHEN CONTROL OR MONITORING RESPONSES ARE EVENT-DRIVEN AS OPPOSED TO TIME OR TIME SCHEDULE-DRIVEN. THE LETTER Y, IN THIS POSITION, CAN ALSO SIGNIFY PRESENCE OR STATE.

21. MODIFYING-LETTER K, IN COMBINATION WITH A FIRST-LETTER SUCH AS L, T, OR W, SIGNIFIES A TIME RATE OF CHANGE OF THE MEASURED OR INITIATING VARIABLE. THE VARIABLE WKIC, FOR INSTANCE, MAY REPRESENT A RATE-OF-WEIGHT-LOSS CONTROLLER

22 SUCCEEDING-LETTER K IS A USER'S OPTION FOR DESIGNATING A CONTROL STATION, WHILE THE SUCCEEDING-LETTER C IS USED FOR DESCRIBING AUTOMATIC OR MANUAL CONTROLLERS

23 A TEST CONNECTION IS A PROCESS CONNECTION TO WHICH NO INSTRUMENT IS PERMANENTLY CONNECTED, BUT WHICH IS INTENDED FOR TEMPORARY, INTERMITTENT, OR FUTURE CONNECTION OF AN INSTRUMENT

PP -DESIGNATES A POINT FOR PRESSURE MEASUREMENT
TW -DESIGNATES EMPTY THERMOWELL
FP -DESIGNATES FLOW POINT WITH UNINSTALLED ELEMENT (ORIFACE FLANGES WITH NO PLATE)
AP -DESIGNATES A FABRICATED CONNECTION DEDICATED TO AN ANALYSIS SUCH AS A VALVED SAMPLE NOZZLE

24 VALVES

- IF A DEVICE MANIPULATES A FLUID PROCESS STREAM AND IS NOT A MANUALLY ACTUATED ON-OFF BLOCK VALVE, IT SHALL BE DESIGNATED AS A CONTROL VALVE.
- A HAND CONTROL VALVE HCV IS A MANUALLY ACTUATED VALVE THAT MODULATES (THROTTLES) A PROCESS STREAM.
- SOLENOID VALVES IN PNEUMATIC SWITCHING SERVICE SHALL BE DESIGNATED AS Y, I.E., FY, HY, JY, ETC SOLENOID VALVES IN PROCESS STREAMS SHALL BE DESIGNATED V, I.E. FV, HV, UV, ETC.
- MOTORIZED VALVES ARE DESIGNATED THE SAME AS OTHER CONTROL VALVES, E.G., FV, PV, HV, ETC
- AN ON-OFF VALVE REMOTELY CONTROLLED BY A HAND-SWITCH IS DESIGNATED AS A HAND VALVE HV.

HAND ELECTRIC SWITCH DESIGNATIONS

E	-EMERGENCY STOP
J	-JOG
E/J	EMERGENCY STOP/JOG
2PBL	-2 PUSH BUTTONS (ON-OFF) MOMENTARY WITH BACK LIGHT(S)
2PB	-2 MOMENTARY PUSH BUTTONS (ON-OFF)
S/J/R	-STOP/JOG/RUN
SW	-SELECTOR SWITCH
HOA	-HAND, OFF, AUTO

USER'S CHOICE DESIGNATIONS

G -
O -

2

A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	JWH	PA	PA	PA	PA	
NO	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR

STARTING DATE 9/12/94 INITIATOR PA / CHKD PA DRAWN JWH / CHKD PA PROJECT MGR P ACHARYA

INTERNATIONAL TECHNOLOGY CORPORATION
Knoxville, Tennessee

PR
3

6	5	4	3	2	1

TYPICAL LETTER COMBINATIONS •

ADOUT DEVICES RDING	ADOUT DEVICES INDICATING	SWITCHES AND ALARM DEVICES •• HIGH•••	LOW	COMB	TRANSMITTERS RECORDING	INDICATING	BLIND	SOLENOIDS, RELAYS, COMPUTING DEVICES	PRIMARY ELEMENT	TEST POINT	WELL OR PROBE	VIEWING DEVICE, GLASS	SAFETY DEVICE	FINAL ELEMENT
	AI	ASH	ASL	ASHL	ART	AIT	AT	AY	AE	AP	AW			AV
	BI	BSH	BSL	BSHL	BRT	BIT	BT	BY	BE		BW	BG		BZ
	EI	ESH	ESL	ESHL	ERT	EIT	ET	EY	EE					EZ
	FI FQI FFI	FSH FCSH FFSH	FSL FQSL FFSL	FSHL	FRT	FIT FQIT	FT FQT	FY FQY	FE FCE FE	FP		FG		FV FQV FFV
				HS										HV
	II	ISH	ISL	ISHL	IRT	IIT	IT	IY	IE					IZ
	JI	JSH	JSL	JSHL	JRT	JIT	JT	JY	JE					JV
	KI	KSH	KSL	KSHL	KRT	KIT	KT	KY	KE					KV
	LI	LSH	LSL	LSHL	LRT	LIT	LT	LY	LE		LW	LG		LV
	PI PDI	PSH PDSH	PSL PDSL	PSHL	PRT PDRT	PIT PDIT	PT PDT	PY PDY	PE PE	PP PP			PSV,PSE	PV PDV
	QI	QSH	QSL	QSHL	QRT	QIT	QT	QY	QE					QZ
	RI	RSH	RSL	RSHL	RRT	RIT	RT	RY	RE		RW			RZ
	SI	SSH	SSL	SSHL	SRT	SIT	ST	SY	SE					SV
	TI TDI	TSH TDSH	TSL TDSL	TSHL	TRT TDRT	TIT TDIT	TT TDT	TY TDY	TE TE	TP TP	TW TW		TSE	TV TDV
	UI							UY						UV
	VI	VSH	VSL	VSHL	VRT	VIT	VT	VY	VE					VZ
	WI WDI	WSH WDSH	WSL WDSL	WSHL	WRT WDRT	WIT WDIT	WT WDT	WY WDY	WE WE					WZ WDZ
	YI	YSH	YSL				YT	YY	YE					YZ
	ZI ZDI	ZSH ZDSH	ZSL ZDSL	ZSHL	ZRT ZDRT	ZIT ZDIT	ZT ZDT	ZY ZDY	ZE ZDE					ZV ZDV

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MOTELY CONTROLLED BY A HAND-
D AS A HAND VALVE HV.

C SWITCH DESIGNATIONS

STOP

OP/JOG

TONS (ON-OFF) MOMENTARY WITH

PUSH BUTTONS (ON-OFF)

JN

ITCH

AUTO

HOICE DESIGNATIONS

3

A
B
C
D
E
F
G
H
I

INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

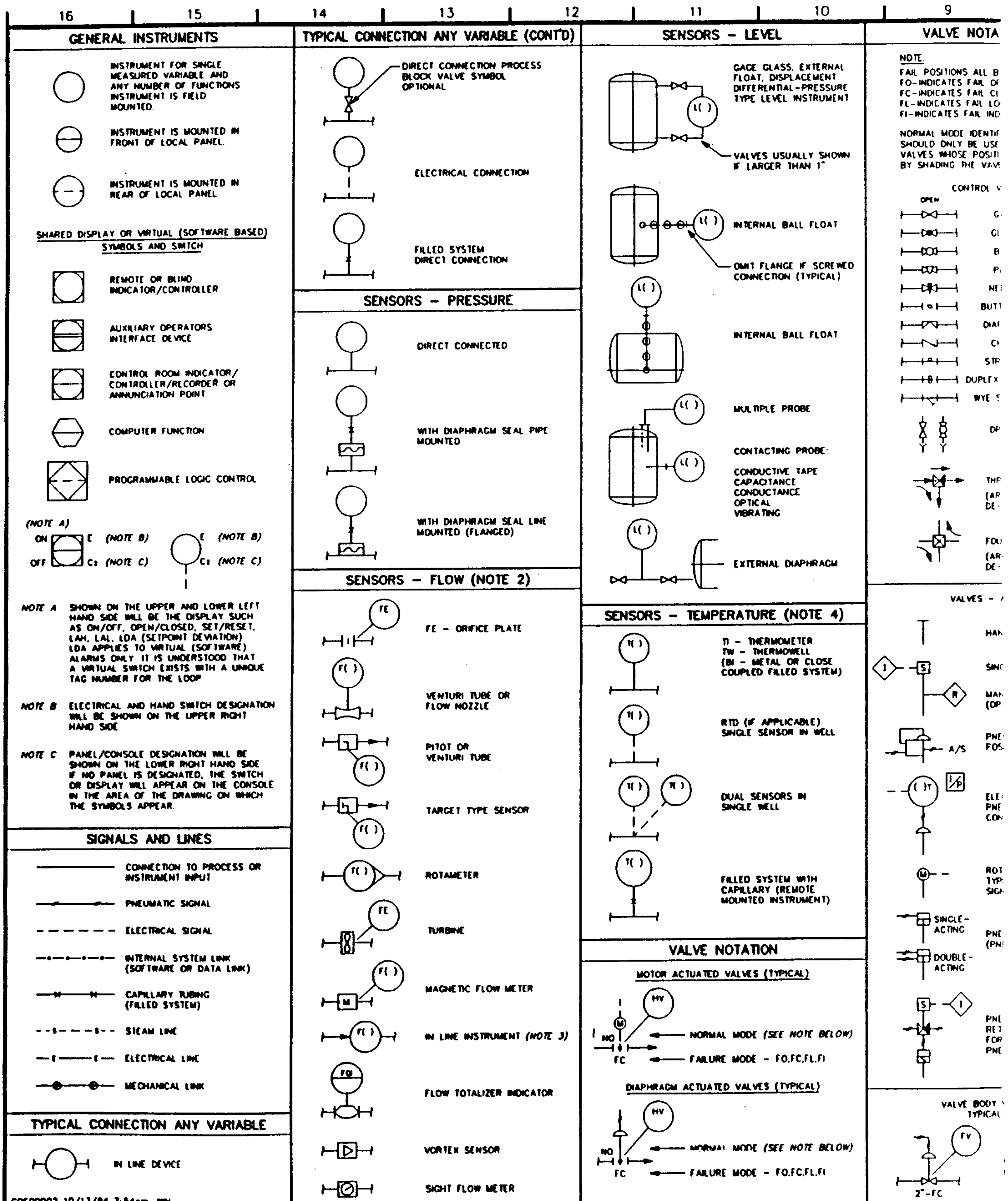
PA	PA	PA	
DSGN CHKR	ENGR	PROJ MGR	APPR

PROJECT
MGR P. ACHARYA

U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

AREA 00
PIPING & INSTRUMENTATION DIAGRAM
INSTRUMENT IDENTIFICATION

PROJ. NO.	DRAWING NO.	REV
322243	D-00-11-001	A



NOTES

1. VALVE-BODY PORTS THAT ARE CLOSED IN NORMAL OPERATION ARE BLACKENED. THE OPERATING CONDITION SHOWN FOR MAIN VALVE BODIES CORRESPONDS TO FULL-LOAD OR NORMAL OPERATION REGARDLESS OF THE TYPE OF ACTUATOR SOLENOID PILOT VALVE SHALL BE SHOWN IN THEIR DEENERGIZED POSITION

2. IDENTIFY BOTH THE ACTUAL ELEMENT WHICH IS PLACED IN THE LINE AND THE INSTRUMENT UNLESS THE DEVICE IS ONE UNIT

   FE ORIFICE PLATE FT TRANSMITTER
   FT MAGNETIC FLOWMETER WITH INTEGRAL TRANSMITTER

3. THE TYPE OF FLOW INSTRUMENT IS USUALLY NAMED OUTSIDE THE INSTRUMENT CIRCLE E.G. MAGNETIC FLOWMETER, DISPLACEMENT METER MASS FLOWMETER

4. TAG THE THERMOWELL SEPARATELY IF IT IS REMOTE MOUNTED FROM THE INSTRUMENT:

   TW, TIC REMOTE CAPILLARY
   TI DIAL THERMOMETER
   TE, TT THERMOCOUPLE AND TRANSMITTER
   TT TRANSMITTER BUILT-IN TO THERMOCOUPLE HEAD.

1

A 10/13/
NO. DATE
STARTING DATE 9

11 10 9 8 7 6 5 4 3

SENSORS – LEVEL

GAGE GLASS, EXTERNAL FLOAT, DISPLACEMENT DIFFERENTIAL–PRESSURE TYPE LEVEL INSTRUMENT

L( )

VALVES USUALLY SHOWN IF LARGER THAN 1"

INTERNAL BALL FLOAT

OMIT FLANGE IF SCREWED CONNECTION (TYPICAL)

INTERNAL BALL FLOAT

MULTIPLE PROBE

CONTACTING PROBE

CONDUCTIVE TAPE
CAPACITANCE
CONDUCTANCE
OPTICAL
VIBRATING

EXTERNAL DIAPHRAGM

NSORS – TEMPERATURE (NOTE 4)

TI – THERMOMETER
TW – THERMOWELL
(BI – METAL OR CLOSE COUPLED FILLED SYSTEM)

RTD (IF APPLICABLE) SINGLE SENSOR IN WELL

DUAL SENSORS IN SINGLE WELL

FILLED SYSTEM WITH CAPILLARY (REMOTE MOUNTED INSTRUMENT)

VALVE NOTATION

MOTOR ACTUATED VALVES (TYPICAL)

HV

NORMAL MODE *(SEE NOTE BELOW)*

FAILURE MODE – FO,FC,FL,FI

DIAPHRAGM ACTUATED VALVES (TYPICAL)

HV

NORMAL MODE *(SEE NOTE BELOW)*

FAILURE MODE – FO,FC,FL,FI

VALVE NOTATION (CONT'D)

NOTE:
FAIL POSITIONS ALL BODY STYLES
FO–INDICATES FAIL OPEN
FC–INDICATES FAIL CLOSED
FL–INDICATES FAIL LOCKED
FI–INDICATES FAIL INDETERMINATE

NORMAL MODE IDENTIFICATION (I.E. NO. NC.) SHOULD ONLY BE USED FOR ON-OFF TYPE VALVES WHOSE POSITION CANNOT BE SHOWN BY SHADING THE VAVE BODY *(NOTE 1)*

CONTROL VALVE BODIES

OPEN		CLOSED
	GATE	
	GLOBE	
	BALL	
	PLUG	
	NEEDLE	
	BUTTERFLY	
	DIAPHRAM	
	CHECK	
	STRAINER	
	DUPLEX STRAINER	
	WYE STRAINER	
	DRAINS	

THREE WAY *(NOTE 1)*
(ARROW SHOWS DE–ENERGIZED PATH)

FOUR WAY *(NOTE 1)*
(ARROW SHOWS DE–ENERGIZED PATH)

VALVES – ACTUATORS

HAND OR HANDWHEEL

SINGLE SOLENOID

MANUAL RESET AFTER LATCH (OPTIONAL)

PNEUMATIC DIAPHRAGM WITH POSITIONER

A/S

ELECTRIC ANALOG SIGNAL TO PNEUMATIC VALVE WITH I/P CONVERTOR AND NO POSITIONER

ROTARY MOTOR (SHOWN TYPICALLY WITH ELECTRIC SIGNAL)

SINGLE–ACTING

DOUBLE–ACTING

PNEUMATIC CYLINDER (PNEUMATIC ANALOG INPUT)

PNEUMATIC CYLINDER SPRING RETURN TO FAIL POSITION FOR ELECTRIC OR PNEUMATIC FAILURE

VALVE BODY WITH ACTUATOR TYPICAL SYMBOLS

FV

NORMALLY OPEN NO POSITIONER

2"-FC

VALVE NOTATION (CONT'D)

FV

NORMALLY CLOSED WITH HANDWHEEL OPERATOR

3"-FC

FV

MAX

MIN

NORMALLY CLOSED WITH MIN AND MAX STOPS

3"-FC

SELF–ACTIVATED DEVICES – PRESSURE

PCV — PRESSURE REDUCING REGULATOR WITH EXTERNAL PRESSURE TAP

PCV — BACKPRESSURE REGULATOR WITH EXTERNAL PRESSURE TAP

PDCV — DIFFERENTIAL PRESSURE REDUCING REGULATOR WITH INTERNAL AND EXTERNAL PRESSURE TAPS

PCV — PRESSURE REDUCING REGULATOR SELF CONTAINED

PCV — BACKPRESSURE REGULATOR SELF–CONTAINED

PRESSURE RELIEF VALVE

PSV — PRESSURE/VACUUM RELIEF VALVE WITH FLAME ARRESTER

PSE — RUPTURE DISK OR SAFETY HEAD FOR PRESSURE RELIEF

PSE — RUPTURE DISK OR SAFETY HEAD FOR VACUUM RELIEF

PCV — H — SPEED CONTROL VALVE

SELF–ACTUATED DEVICES – LEVEL

LCV — LEVEL REGULATOR WITH MECHANICAL LINKAGE

SELF–ACTUATED DEVICES · TEMPERATURE

TCV TW — TEMPERATURE REGULATOR FILLED SYSTEM TYPE

SELF–ACTIVATE DEVICES – PRESSURE (CONT'D)

SELF–ACTUATED DEVICES – FLOW

(UP–STREAM VALVE)

FVC

(DOWN–STREAM VALVE)

ROTAMETER WITH VALVE SELF–CONTAINED (DIFFERENTIAL REGULATORS WILL NOT BE SHOWN)

(UP–STREAM VALVE)

FVC

ROTAMETER WITH VALVE SELF–CONTAINED (DIFFERENTIAL REGULATORS WILL NOT BE SHOWN)

FUNCTION SYMBOLS

Symbol	Function
Σ	SUMMING
Σ/n	AVERAGING
Δ	DIFFERENCE
K	
1:1	PROPORTIONAL
2:1	
∫	INTEGRAL
d/dt	DERIVATIVE
x	MULTIPLYING
÷	DIVIDING
n√	ROOT EXTRACTION
x^n	EXPONENTIAL
f(x)	NONLINEAR OR UNSPECIFIED FUNCTION
f(t)	TIME FUNCTION
>	HIGH SELECTING
<	LOW SELECTING
	HIGH LIMITING
	LOW LIMITING
-K	REVERSE PROPORTIONAL
	VELOCITY LIMITER
+	
-	BIAS
±	
/	CONVERT

MISCELLANEOUS SYMBOLS

AS — FICV

PURGE FLUID AND UTILITY SUPPLIES ARE:
AS–AIR SUPPLY
GS–GAS SUPPLY
HS–HYDRAULIC FLUID SUPPLY
NS–NITROGEN SUPPLY
SS–STEAM SUPPLY
WS–WATER SUPPLY

PLANT AIR REGULATOR

TRUMENT IS USUALLY NAMED OUTSIDE THE INSTRUMENT CIRCLE
ER, DISPLACEMENT METER MASS FLOWMETER

EPARATELY IF IT IS REMOTE MOUNTED FROM THE INSTRUMENT

LLARY
METER
LE AND TRANSMITTER
BUILT–IN TO THERMOCOUPLE HEAD

NO	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR
A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	JWH	PA	PA	PA	PA	

STARTING DATE 9/12/94 · INITIATOR PA · CHKD PA · DRAWN JWH · CHKD PA · PROJECT MGR P. ACHARYA

2

INTERNATIONAL TECHNOLOGY CORPORATION
Knoxville, Tennessee

U.S.
ABERDE

PIPIN
C

PROJ. NO
322243

7 | 6 | 5 | 4 | 3 | 2 | 1

VALVE NOTATION (CONT'D)

FV — NORMALLY CLOSED WITH HANDWHEEL OPERATOR (3"-FC)

FV — NORMALLY CLOSED WITH MIN AND MAX STOPS (MAX, MIN, 3"-FC)

SELF-ACTIVATED DEVICES – PRESSURE

PCV — PRESSURE REDUCING REGULATOR WITH EXTERNAL PRESSURE TAP

PCV — BACKPRESSURE REGULATOR WITH EXTERNAL PRESSURE TAP

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SELF-ACTUATED DEVICES – TEMPERATURE

TW — TEMPERATURE REGULATOR FILLED SYSTEM TYPE

SELF-ACTIVATE DEVICES – PRESSURE (CONT'D)

SELF-ACTUATED DEVICES – FLOW

FVC — (UP-STREAM VALVE) (DOWN-STREAM VALVE) — ROTAMETER WITH VALVE SELF-CONTAINED (DIFFERENTIAL REGULATORS WILL NOT BE SHOWN)

FVC — (UP-STREAM VALVE) — ROTAMETER WITH VALVE SELF-CONTAINED (DIFFERENTIAL REGULATORS WILL NOT BE SHOWN)

FUNCTION SYMBOLS

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MISCELLANEOUS SYMBOLS

AS — FICV — PURGE FLUID AND UTILITY SUPPLIES ARE:

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- NS-NITROGEN SUPPLY
- SS-STEAM SUPPLY
- WS-WATER SUPPLY

PLANT AIR REGULATOR

MISCELLANEOUS SYMBOLS (CONT'D)

DETONATION ARRESTOR

FLAME ARRESTOR

S — TRAP

IAS — REGULATED INSTRUMENT AIR SUPPLY

A | B | C | D | E | F | G | H | I | J

JMH	PA	PA	PA	PA	
BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR

CHKD PA — PROJECT MGR P. ACHARYA

INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

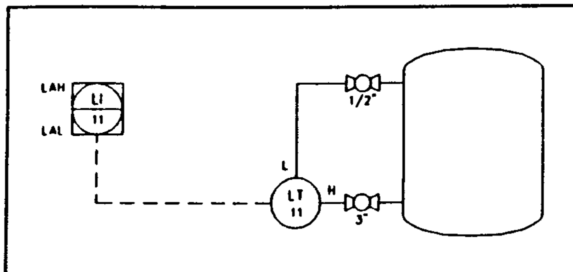
(3)

U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

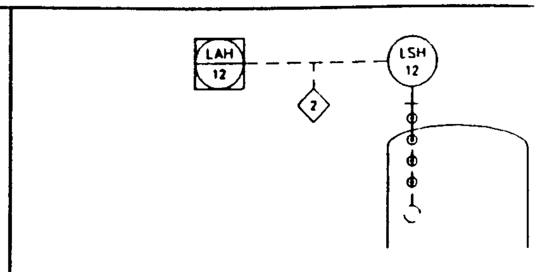
AREA 00
PIPING & INSTRUMENTATION DIAGRAM
CONTROL SYSTEM STANDARDS

PROJ. NO.	DRAWING NO.	REV
322243	D-00-11-002	A

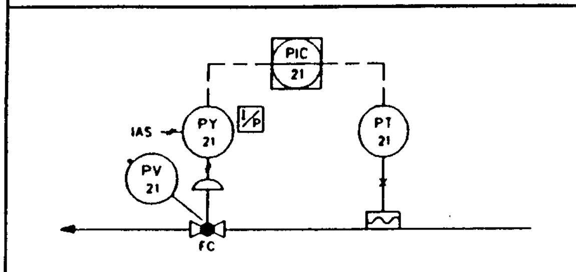
16 15 14 13 12 11 10 9



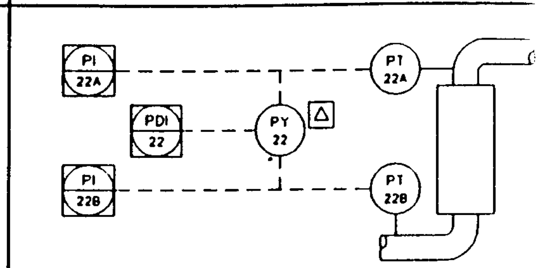
LEVEL INDICATOR WITH ALARMS SHOWN ON SHARED DISPLAY USING DIAPHRAGM TYPE TRANSMITTER ON A PRESSURIZED VESSEL.



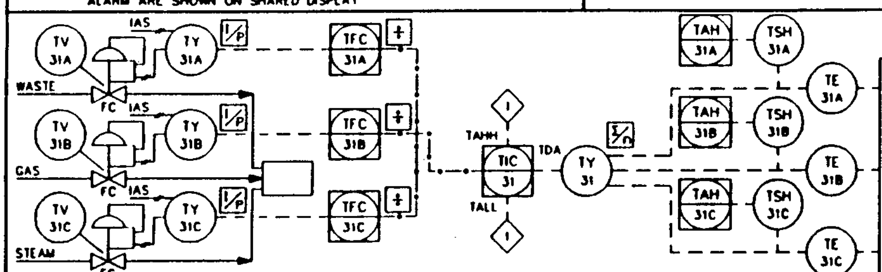
LEVEL ALARM USING FLOAT TYPE SWITCH ALARM CONDITION IS PART OF INTERLOCK 2.



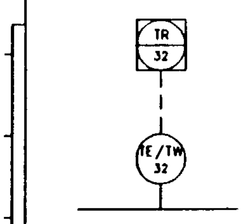
BACK PRESSURE REGULATOR USING A PRESSURE TRANSMITTER W/CAPILLARY AND CHEMICAL SEAL. PRESSURE CONTROLLER AND ALARM ARE SHOWN ON SHARED DISPLAY



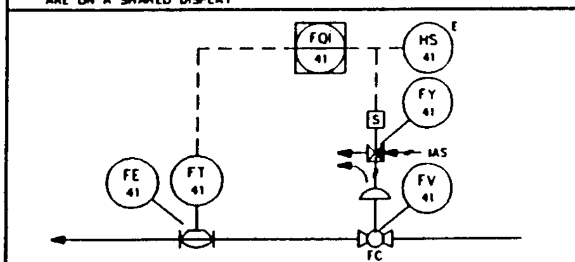
DIFFERENTIAL PRESSURE INDICATOR USING TWO PRESSURE TRANSMITTERS



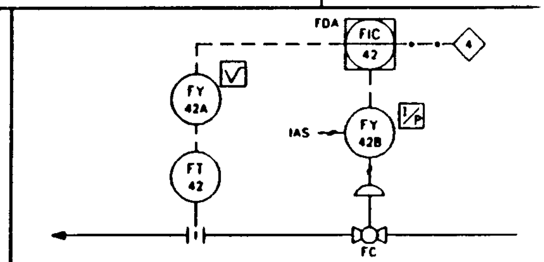
TEMPERATURE CONTROL LOOP, AVERAGING THERMOCOUPLE INPUTS AND ALARMS ON BURN OUT. CONTROLLER OUTPUT IS RATIOED SEPARATELY TO THREE CONTROL VALVES WITH POSITIONERS. CONTROLLER, RATIO STATIONS AND ALARMS ARE ON A SHARED DISPLAY



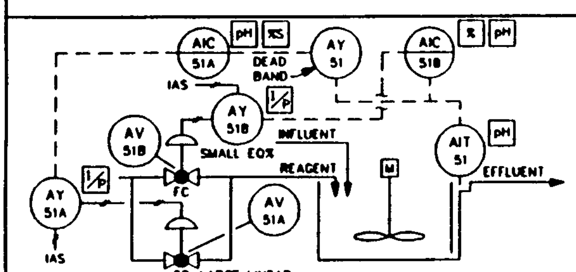
SINGLE PEN TEMPERATURE RECORDER W/THERMOCOUPLE INPUT



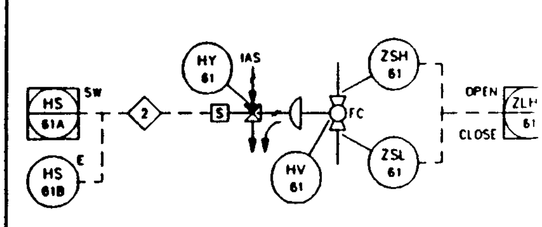
BATCH TOTALIZER USING A POSITIVE DISPLACEMENT METER WITH A PULSE OUTPUT. THE HS IS A LOCAL MOUNTED EMERGENCY STOP.



FLOW CONTROL LOOP USING AN ORIFICE PLATE AS THE SENSING ELEMEN SQUARE ROOT EXTRACTOR IS USED TO LINEARIZE THE FLOW SIGNAL. THE ALARMS ARE PART OF INTERLOCK 4.



pH CONTROL LOOP FOR A CONSTANT INFLUENT FLOW AND A WIDE RANGEABILITY OF pH. AIC-51 B CONTROL pH AROUND THE SET POINT. IF DEVIATION IS TOO MUCH, AY-51 WILL ALLOW AIC-51 A TO START ADDING REAGENT



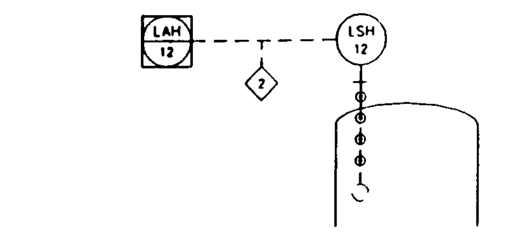
REMOTE OPERATED ON-OFF CONTROL VALVE, ON-OFF SWITCH AND VALVE POSITION INDICATORS SHOWN ON A SHARED DISPLAY. A LOCAL EMERGENC CLOSE IS INCLUDED. THE VALVE IS PART OF INTERLOCK SEQUENCE 2

COE00D03 10/13/94 7:57am JWH

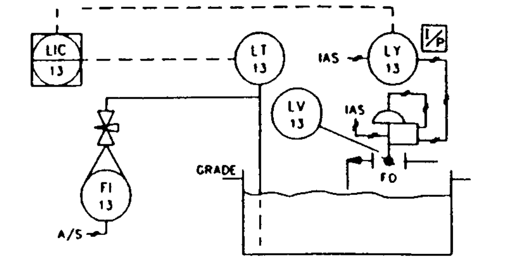
NOTES

1

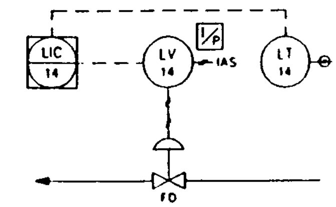
2 11 10 9 8 7 6 5 4



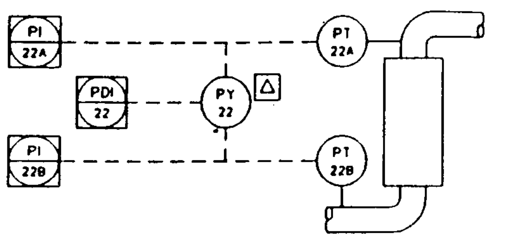
LEVEL ALARM USING FLOAT TYPE SWITCH. ALARM CONDITION IS PART OF INTERLOCK 2.



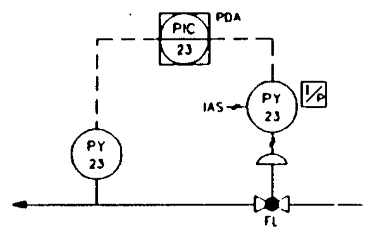
LEVEL CONTROL LOOP USING A BUBBLE TUBE IN CONJUNCTION WITH A LEVEL TRANSMITTER. A POSITIONER IS USED ONLY ON LARGE BUTTERFLY VALVES



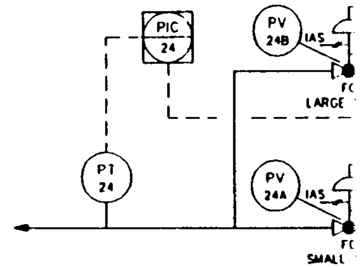
LEVEL CONTROL LOOP USING BUOYANCY LEVEL



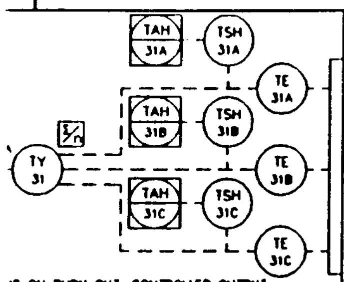
DIFFERENTIAL PRESSURE INDICATOR USING TWO PRESSURE TRANSMITTERS



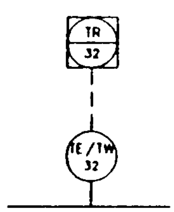
PRESSURE REDUCING STATION USING A CONTROLLER SHOWN ON A SHARED DISPLAY



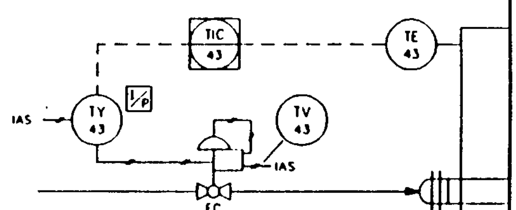
PRESSURE CONTROL LOOP USING SPLIT RANGE CONTR LOAD CONDITION THE SMALL VALVE IS THROTTLING ON VALVE IS THROTTLING, SMALL VALVE IS OPEN



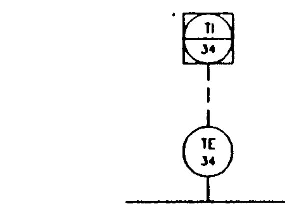
'S ON BURN OUT. CONTROLLER OUTPUT ROLLER, RATIO STATIONS AND ALARMS



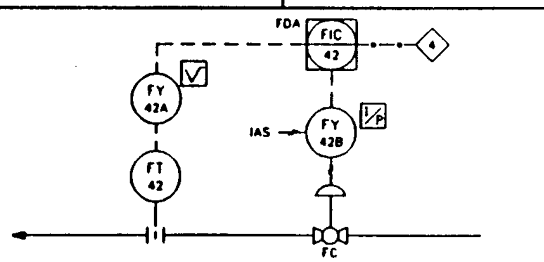
SINGLE PEN TEMPERATURE RECORDER W/THERMOCOUPLE INPUT



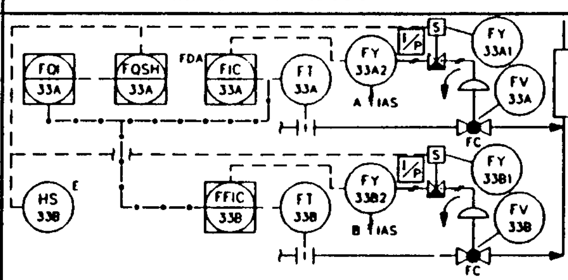
TEMPERATURE CONTROL LOOP USING A THERMOCOUPLE AS A SENSING ELEMENT. THE CONTROL VALVE IS PNEUMATIC ACTUATED WITH A POSITIONER. CONTROLLER IS ON A SHARED DISPLAY



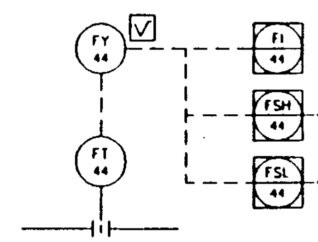
REMOTE TEMPERTAURE INDICATOR SHOWN ON A SHA A THERMOCOUPLE AS A SENSING ELEMENT



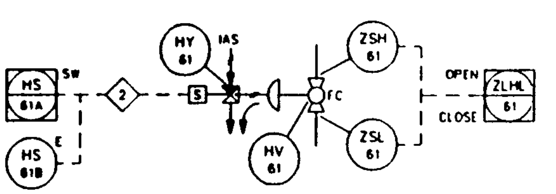
FLOW CONTROL LOOP USING AN ORIFICE PLATE AS THE SENSING ELEMENT. SQUARE ROOT EXTRACTOR IS USED TO LINEARIZE THE FLOW SIGNAL. THE ALARMS ARE PART OF INTERLOCK 4.



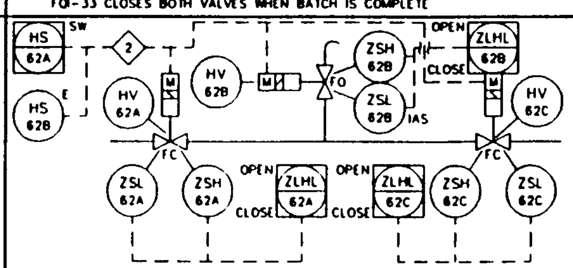
FLOW RATIO CONTROL LOOP THAT IS OPERATED ON A BATCH BASIS. THE FLOW OF A SETS THE SETPOINT OF FIC-33 B VIA A RATIO STATION. FQI-33 CLOSES BOTH VALVES WHEN BATCH IS COMPLETE



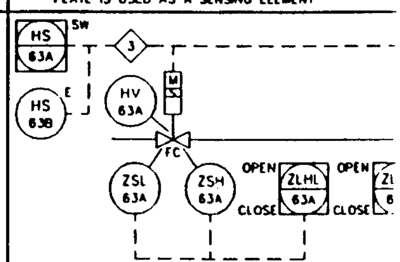
REMOTE FLOW INDICATOR SHOWN ON A SHARED DISP ROOT EXTRACTOR IS USED TO LINEARIZE THE FLOW PLATE IS USED AS A SENSING ELEMENT



REMOTE OPERATED ON-OFF CONTROL VALVE. ON-OFF SWITCH AND VALVE POSITION INDICATORS SHOWN ON A SHARED DISPLAY. A LOCAL EMERGENCY CLOSE IS INCLUDED. THE VALVE IS PART OF INTERLOCK SEQUNECE 2



DOUBLE BLOCK AND BLEED FOR GAS SERVICE. BLOCK VALVES ARE MOTOR DRIVEN OPEN AND SPRING CLOSED. BLEED VALVE IS MOTOR DRIVEN CLOSED AND SPRING OPEN. ALL VALVES ARE PART OF INTERLOCK 2



DOUBLE BLOCK FOR LIQUID SERVICE. BLOCK VALVES AR OR MOTOR DRIVEN OPEN AND SPRING CLOSED DEPENDI MATERIALS. ALL VALVES ARE PART OF INTERLOCK 3

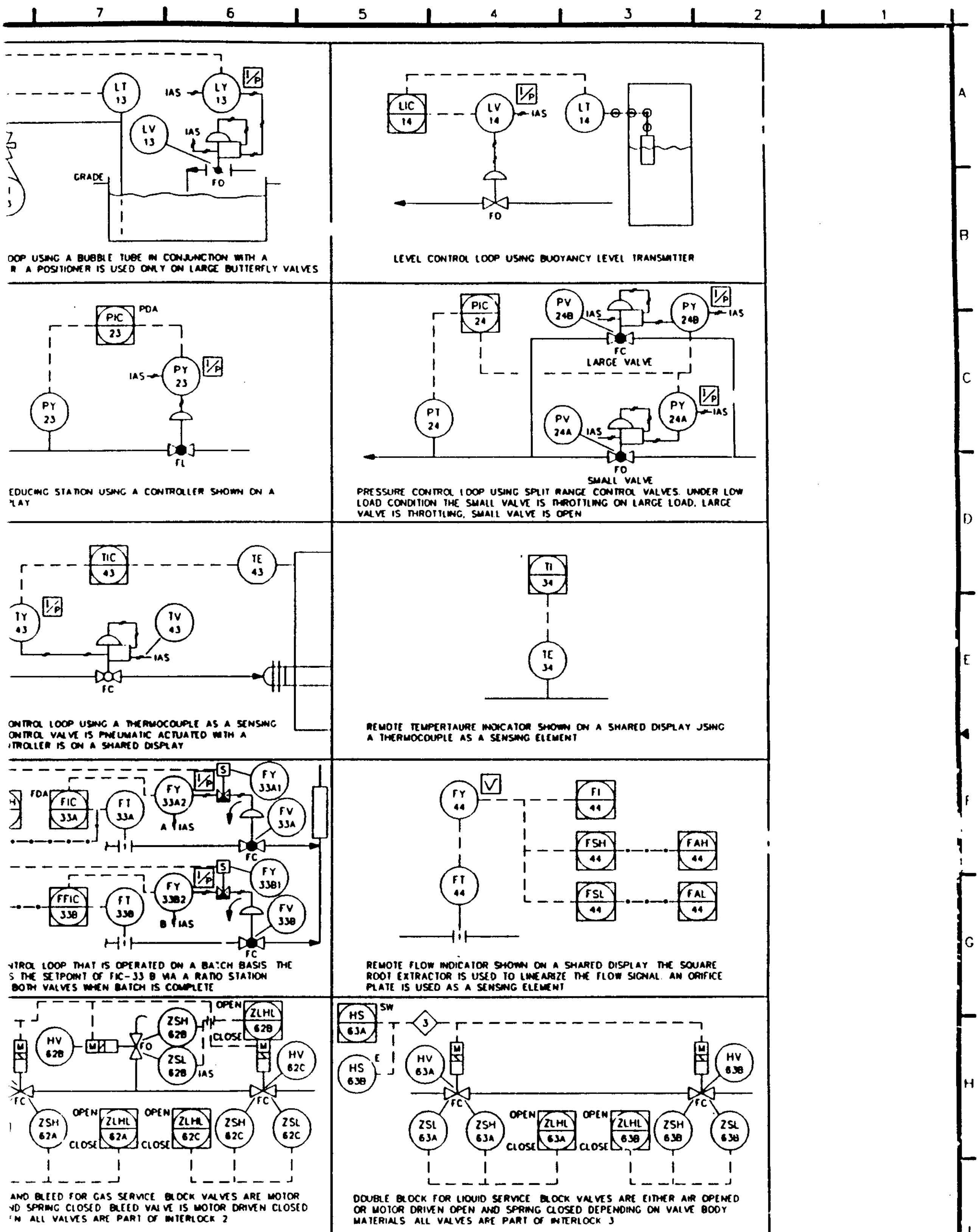
INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

NO	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR
A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	JWH	PA	PA	PA	PA	

STARTING DATE 9/12/94 INITIATOR PA / CHKD PA DRAWN JWH / CHKD PA PROJECT MGR P. ACHARYA

PR(3:



TO USAEC	JWH	PA	PA	PA	PA	
	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR
PA	DRAWN JWH	CHKD PA	PROJECT MGR P. ACHARYA			

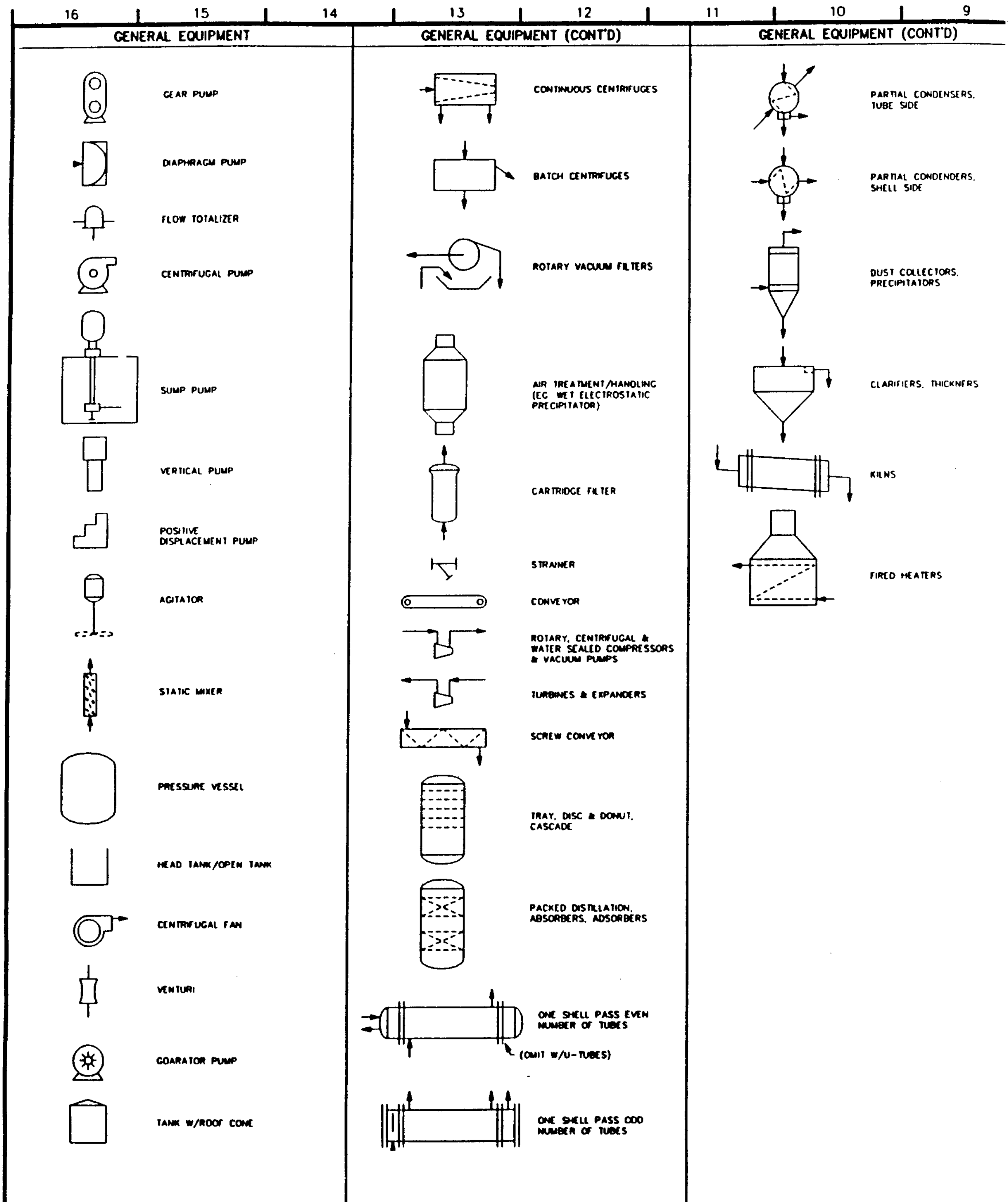
INTERNATIONAL TECHNOLOGY CORPORATION
Knoxville, Tennessee

3

U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

AREA 00
PIPING & INSTRUMENTATION DIAGRAM
CONTROL LOOP STANDARDS

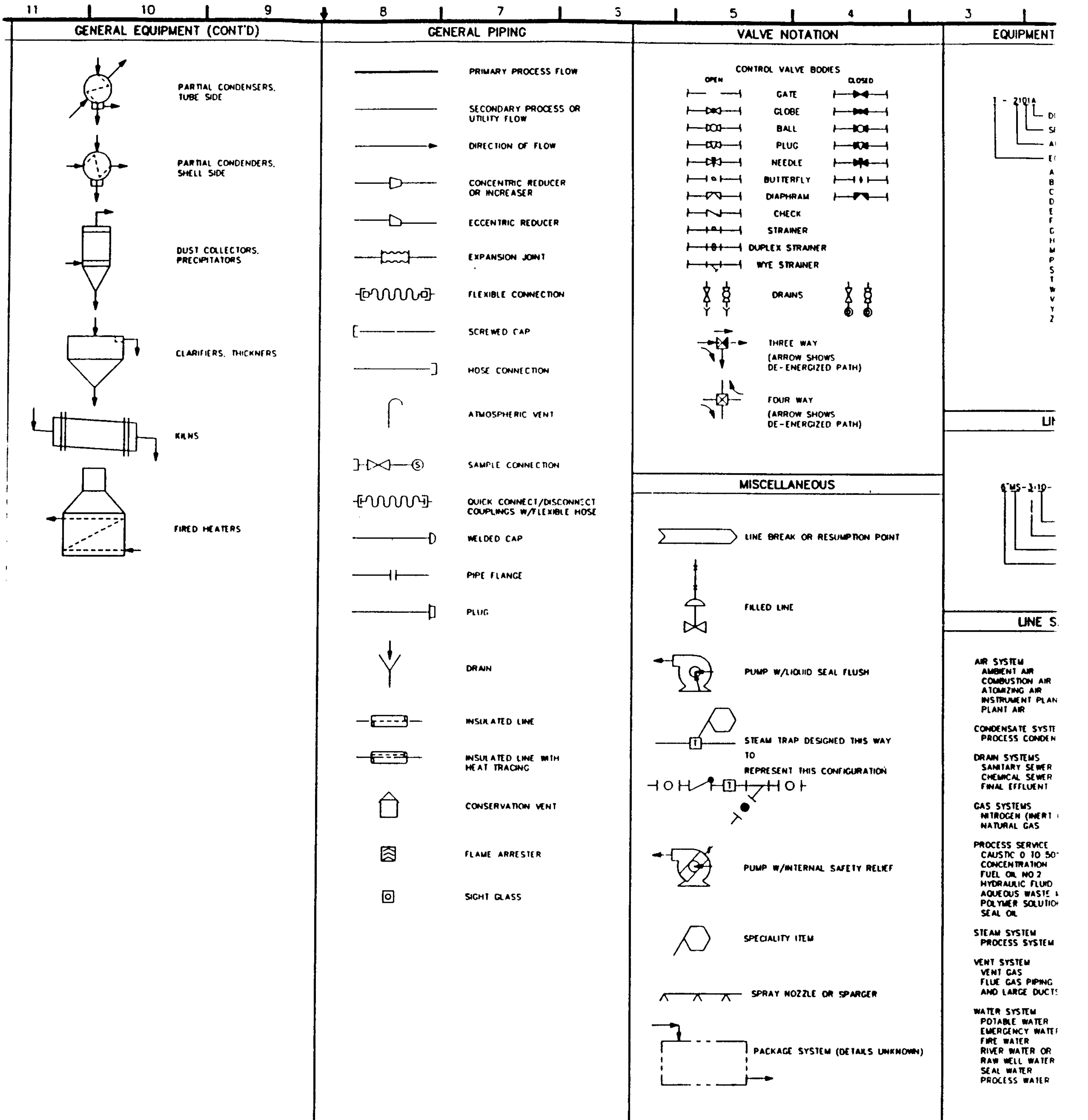
PROJ. NO.	DRAWING NO.	REV
322243	D-00-11-003	A



COE00D04 10/13/94 8:00am JWH

NOTES

1



2

NO	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR
A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	JWH	PA	PA	PA	PA	

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INTERNATIONAL TECHNOLOGY CORPORATION

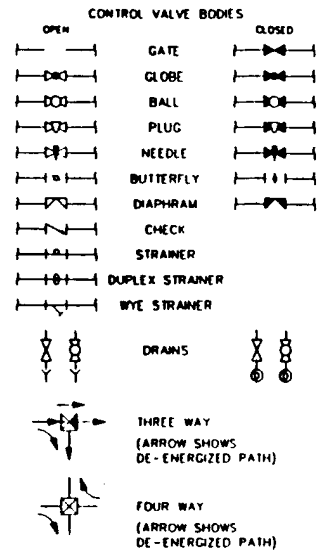
Knoxville, Tennessee

U.S. ARMY EN
ABERDEEN PRO

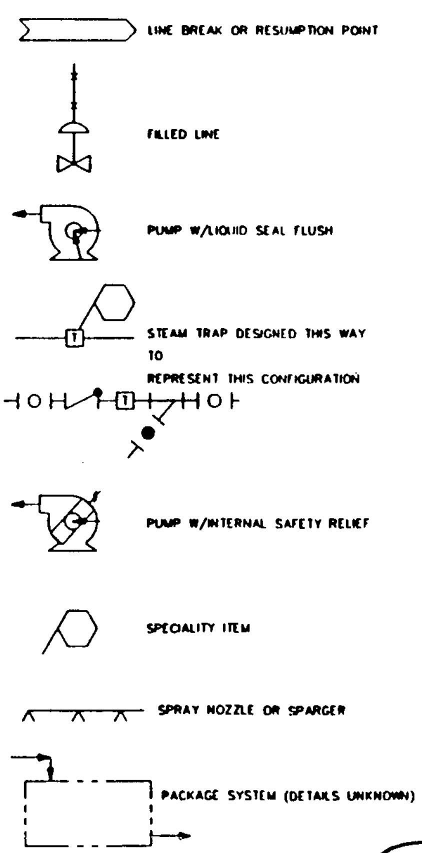
PIPING & INST
EQUIPME

PROJ. NO.
322243

VALVE NOTATION



MISCELLANEOUS



EQUIPMENT NUMBER IDENTIFICATION

T - 2101A

- A — DUPLICATE OR SPARE
- 01 — SEQUENCE NUMBER
- 21 — AREA NUMBER
- T — EQUIPMENT LETTER (SEE BELOW)

A - AGITATOR
B - BLOWER
C - COLUMN
D - DRYER (MOLECULAR SIEVE)
E - HEAT EXCHANGER
F -
G - EVAPORATOR
H - SOLIDS, HANDLING EQUIPMENT
M - MIXER, BLENDER
P - PUMP
S -
T - TANK
W - COOLING WATER
V - BURNER
Y - MISCELLANEOUS
Z - MISCELLANEOUS DEMISTER

LINE IDENTIFICATION

6"MS-3-10-C

- C — PIPING SPECIFICATION
- 10 — LINE NUMBER
- 3 — AREA NUMBER
- MS — LINE SERVICE DESIGNATION
- 6" — LINE SIZE

LINE SERVICE DESIGNATION

	LINE SERVICE DESIGNATION	PIPING SPEC
AIR SYSTEM		
AMBIENT AIR	AA	G
COMBUSTION AIR	DA	Q
ATOMIZING AIR	GA	G
INSTRUMENT PLANT AIR	IA	P
PLANT AIR	PA	C
CONDENSATE SYSTEM		
PROCESS CONDENSATE	PC	D
DRAIN SYSTEMS		
SANITARY SEWER	KW	
CHEMICAL SEWER	LW	N
FINAL EFFLUENT	WW	N
GAS SYSTEMS		
NITROGEN (INERT GAS)	N	E
NATURAL GAS	NG	B
PROCESS SERVICE		
CAUSTIC 0 TO 50% CONCENTRATION	CA	X
FUEL OIL NO.2	FO	A
HYDRAULIC FLUID	HO	CA
AQUEOUS WASTE MIXTURE	PL	AA
POLYMER SOLUTIONS	PL	J
SEAL OIL	SO	A
STEAM SYSTEM		
PROCESS SYSTEM	PS	D
VENT SYSTEM		
VENT GAS	EC	E
FLUE GAS PIPING AND LARGE DUCTS	FG	R
WATER SYSTEM		
POTABLE WATER	DW	H
EMERGENCY WATER	EW	N
FIRE WATER	FW	N
RIVER WATER OR RAW WELL WATER	RW	A
SEAL WATER	SW	A
PROCESS WATER	UW	N

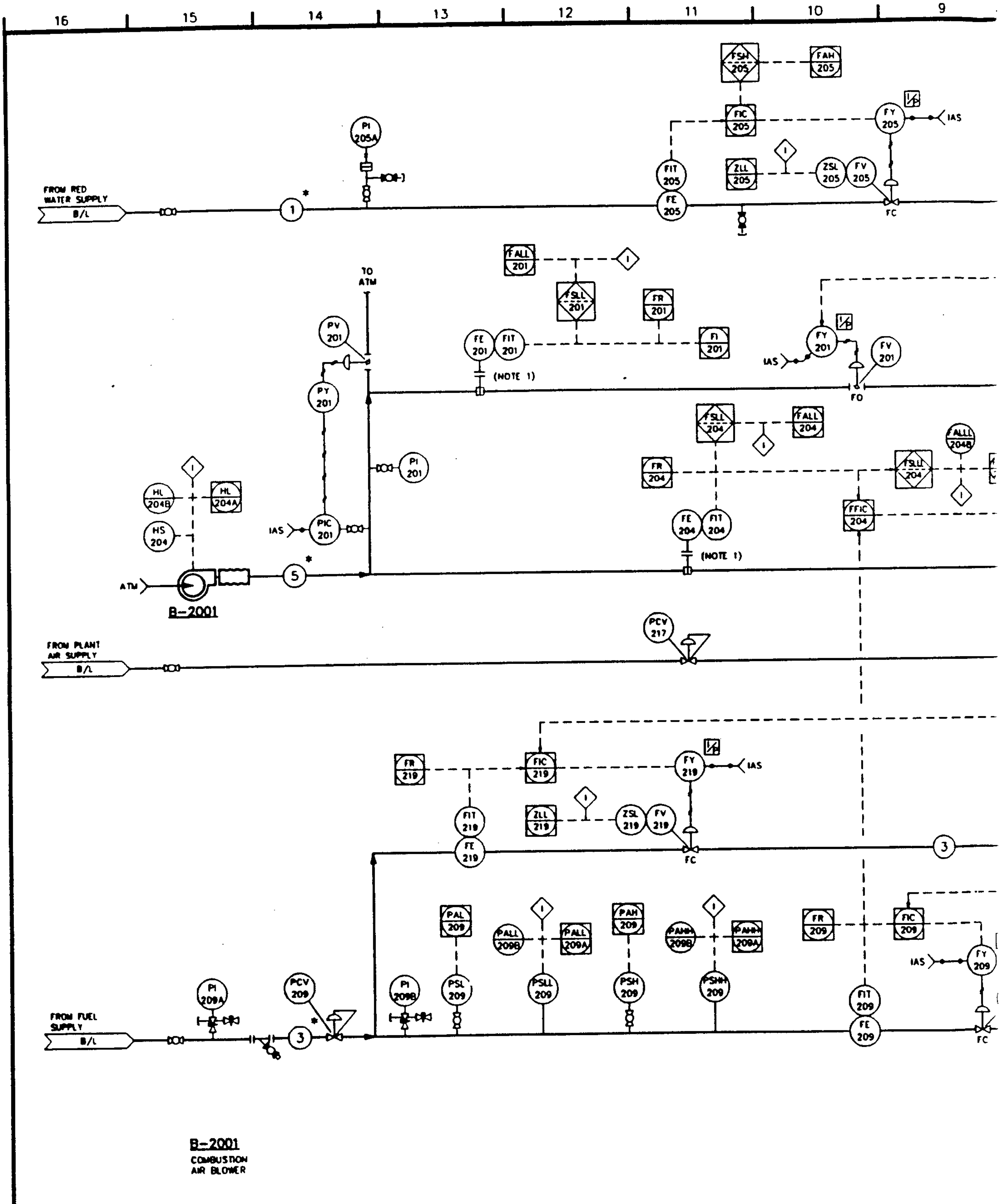
3

INTERNATIONAL TECHNOLOGY CORPORATION
Knoxville, Tennessee

U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

AREA 00
PIPING & INSTRUMENTATION DIAGRAM
EQUIPMENT IDENTIFICATION

PROJ. NO.	DRAWING NO.	REV
322243	D-00-11-004	A

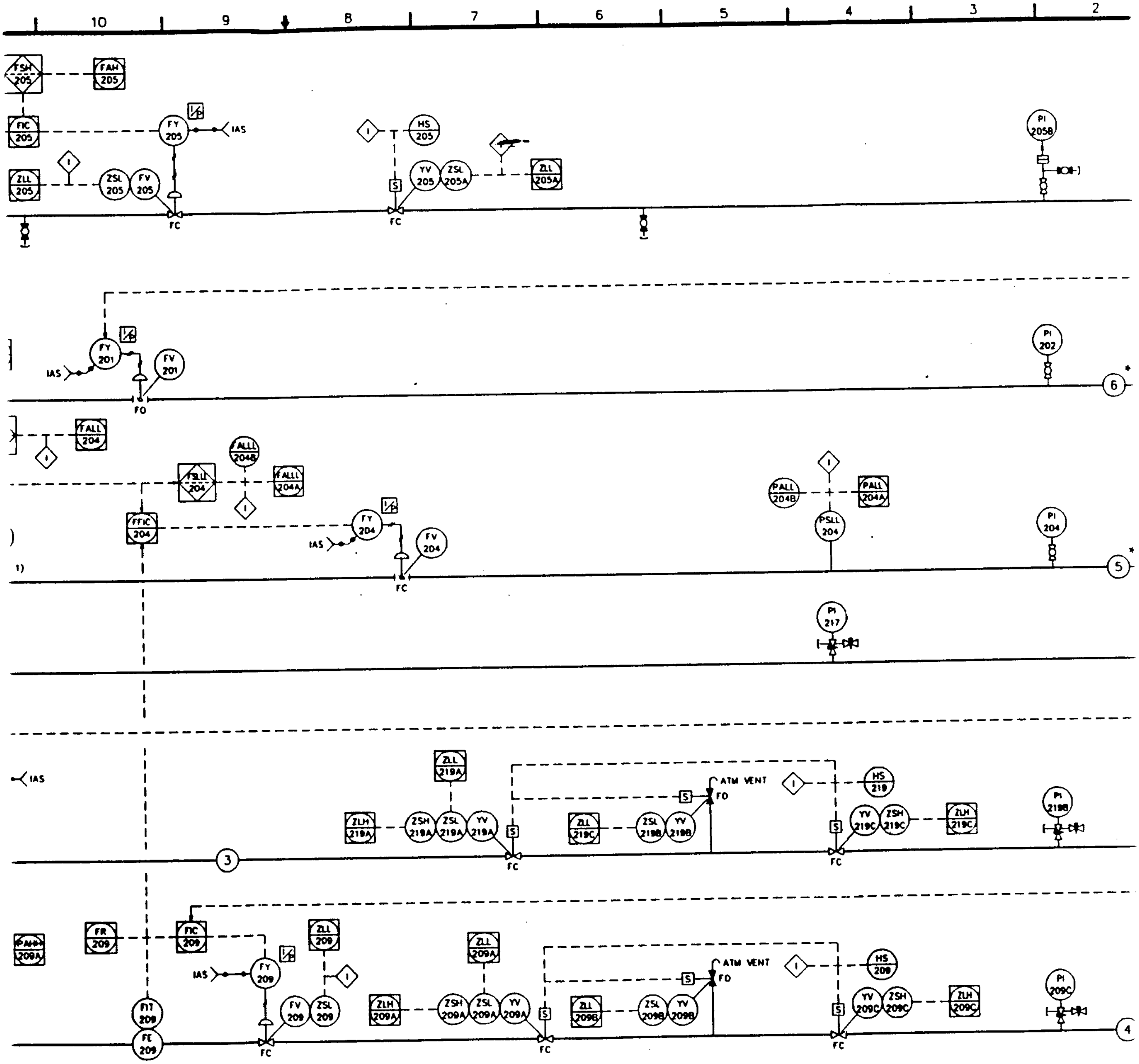


NOTES

1. FLOW METER TO BE INSTALLED IN STRAIGHT SECTION OF DUCT. A MINIMUM OF 10 DIAMETERS DOWNSTREAM AND 5 DIAMETERS UPSTREAM OF ANY BENDS, EQUIPMENT, OR OTHER DISTURBANCES IN THE DUCT.

2. * LINE NUMBERS USED FOR HAZOP ANALYSIS

①



NO	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR
A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	JWH	PA	WMS	PO	PA	

STARTING DATE 9/12/94 | INITIATOR WMS / CHKD PA | DRAWN JWH / CHKD WMS | PROJECT MGR P. ACHARYA

INTERNATIONAL TECHNOLOGY CORPORATION

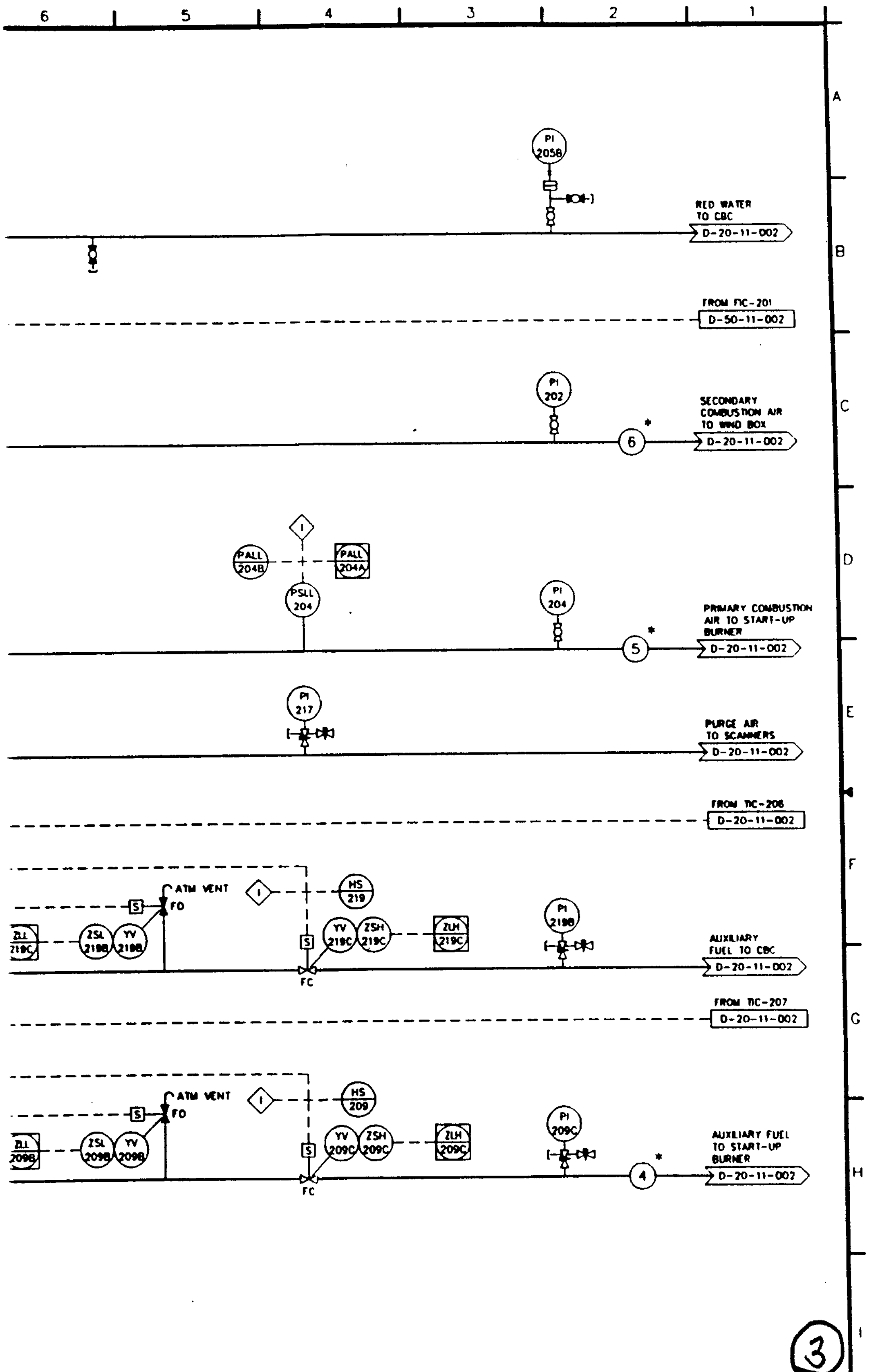
Knoxville, Tennessee

2

U.S. ARMY ENVIRON
ABERDEEN PROVING G

AREA
PIPING & INSTRUME
CBC BURNE

PROJ. NO.	D
322243	D-



INTERNATIONAL TECHNOLOGY CORPORATION

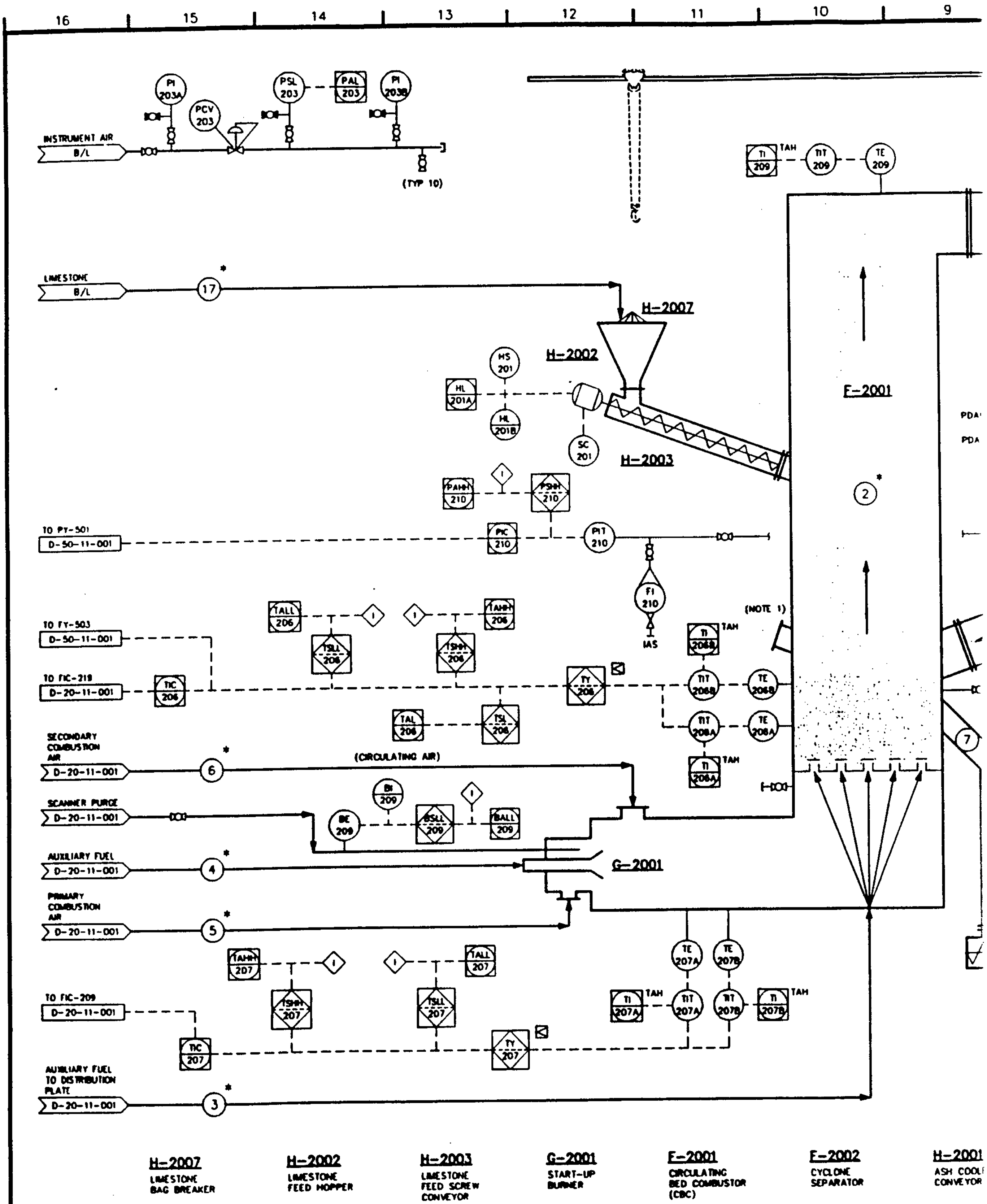
Knoxville, Tennessee

U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

AREA 20
PIPING & INSTRUMENTATION DIAGRAM
CBC BURNER SYSTEM

PROJ. NO.	DRAWING NO.	REV
322243	D-20-11-001	A

A
APPR
CHARYA

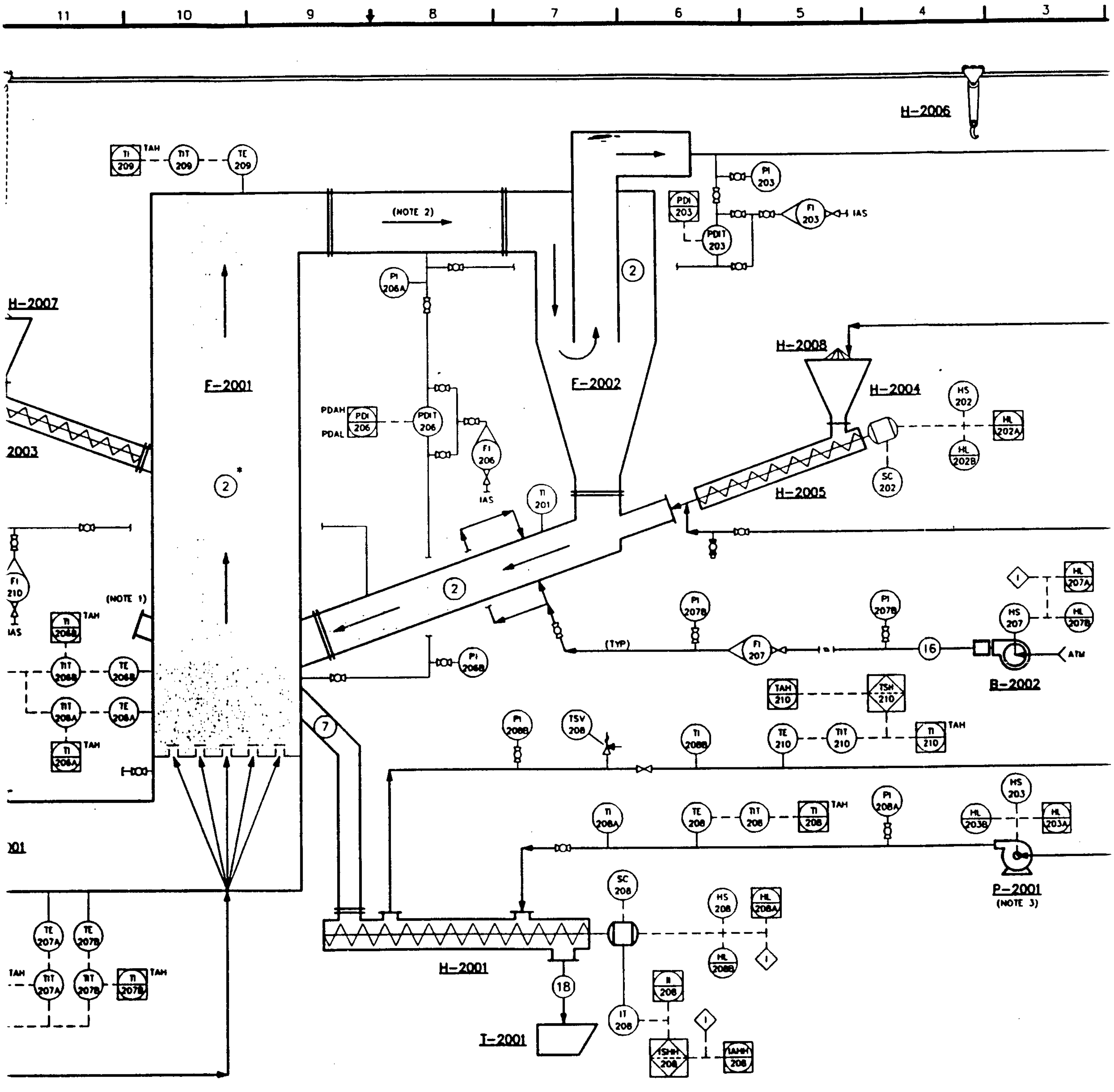


32224305 01/18/95 8:37am JMH

NOTES

1 ALTERNATE START-UP BURNER LOCATION.
2 A PITOT-TUBE WILL BE LOCATED TO MEASURE GAS FLOW DURING TESTING ONLY.
3 COOLING WATER RECIRCULATION PUMP MAY NOT BE REQUIRED AND IS OPTIONAL
4 * LINE NUMBERS USED FOR HAZOP ANALYSIS

1



F-2001	F-2002	H-2001	I-2001	H-2006	H-2008	H-2004	H-2005	B-2002
CIRCULATING BED COMBUSTOR (CBC)	CYCLONE SEPARATOR	ASH COOLER CONVEYOR	ASH BIN	HOIST	Al_2O_3 BAG BREAKER	Al_2O_3 FEED HOPPER	Al_2O_3 FEED SCREW CONVEYOR	LOOP-SEAL PURGE AIR BLOWER

2

A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	JWH	PA	WMS	PO	PA	
NO.	DATE	REVISION	BY	CHKD	DSGN ENGR	CHKR	PROJ MGR	APPR

STARTING DATE 9/12/94 INITIATOR WMS / CHKD PA DRAWN JWH / CHKD WMS PROJECT MGR P. ACHARYA

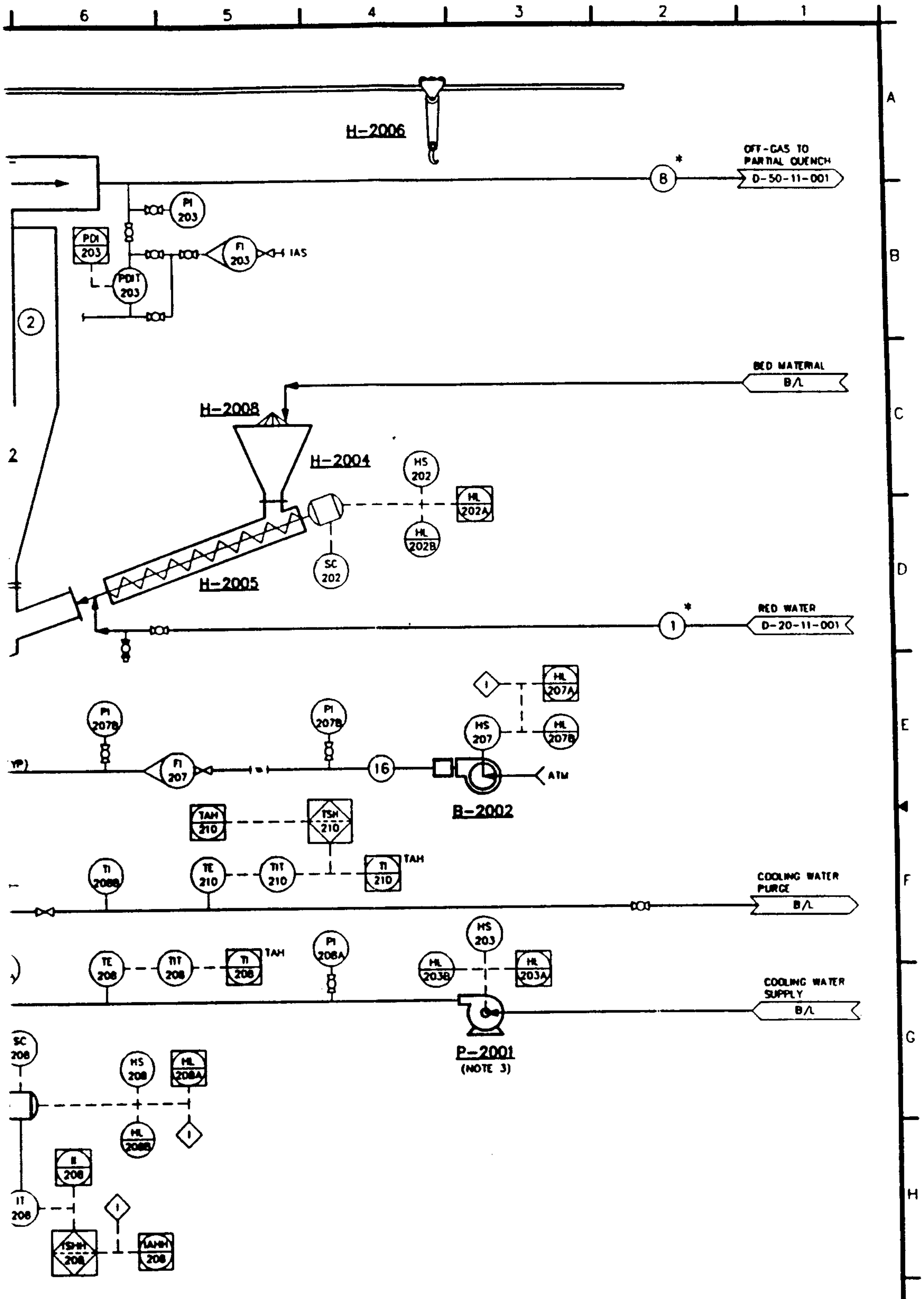
INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

U.S. A
ABERDEE

PIPING
CIR

PROJ. NO.
322243



H-2008
Al_2O_3 BAG BREAKER

H-2004
Al_2O_3 FEED HOPPER

H-2005
Al_2O_3 FEED SCREW CONVEYOR

B-2002
LOOP-SEAL PURGE AIR BLOWER

P-2001
COOLING WATER RECIRCULATION PUMP

INTERNATIONAL TECHNOLOGY CORPORATION
Knoxville, Tennessee

PO	PA	
ENGR	PROJ MGR	APPR

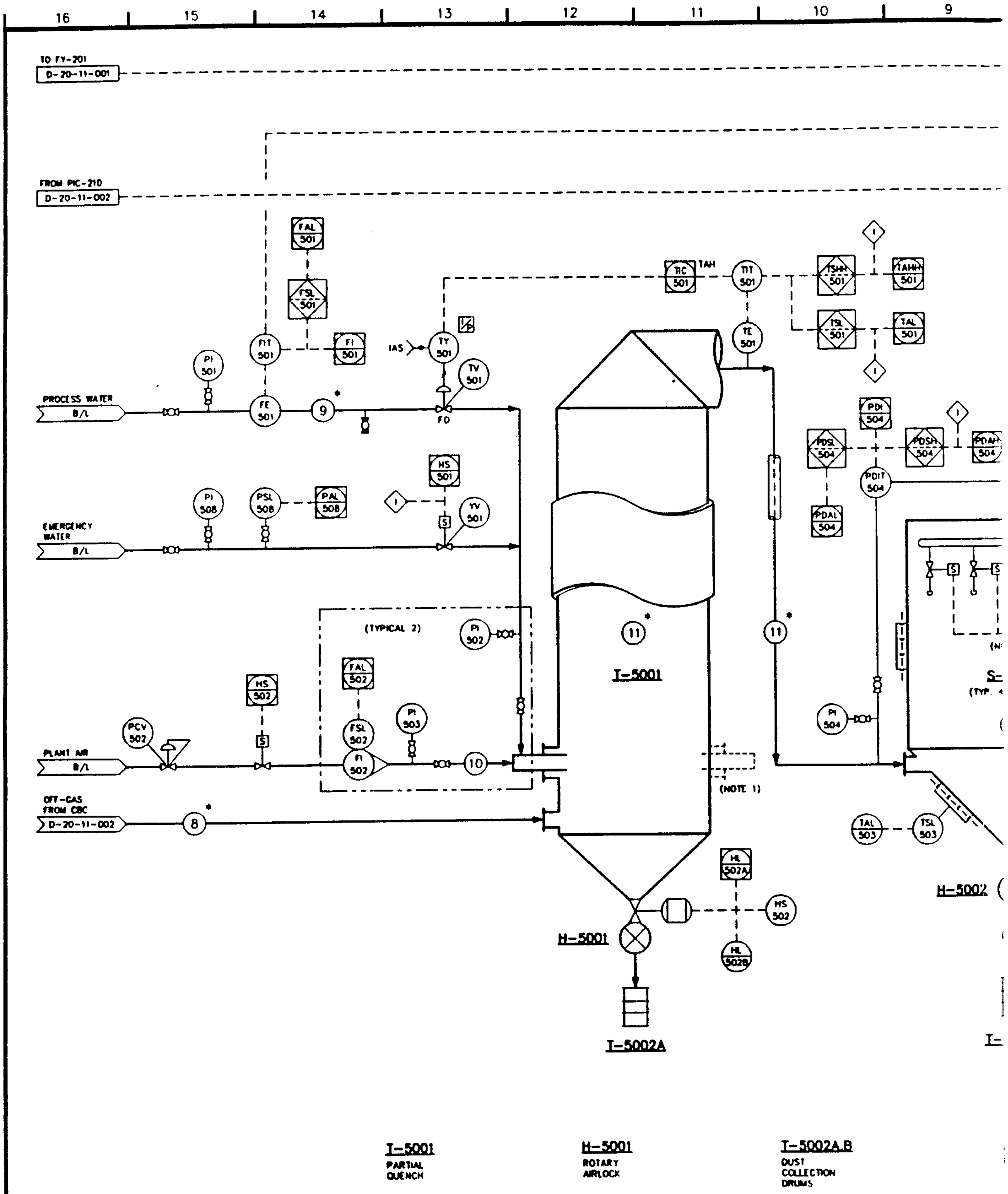
P. ACHARYA

3

U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

AREA 20
PIPING & INSTRUMENTATION DIAGRAM
CIRCULATING BED COMBUSTOR

PROJ. NO.	DRAWING NO.	REV
322243	D-20-11-002	A

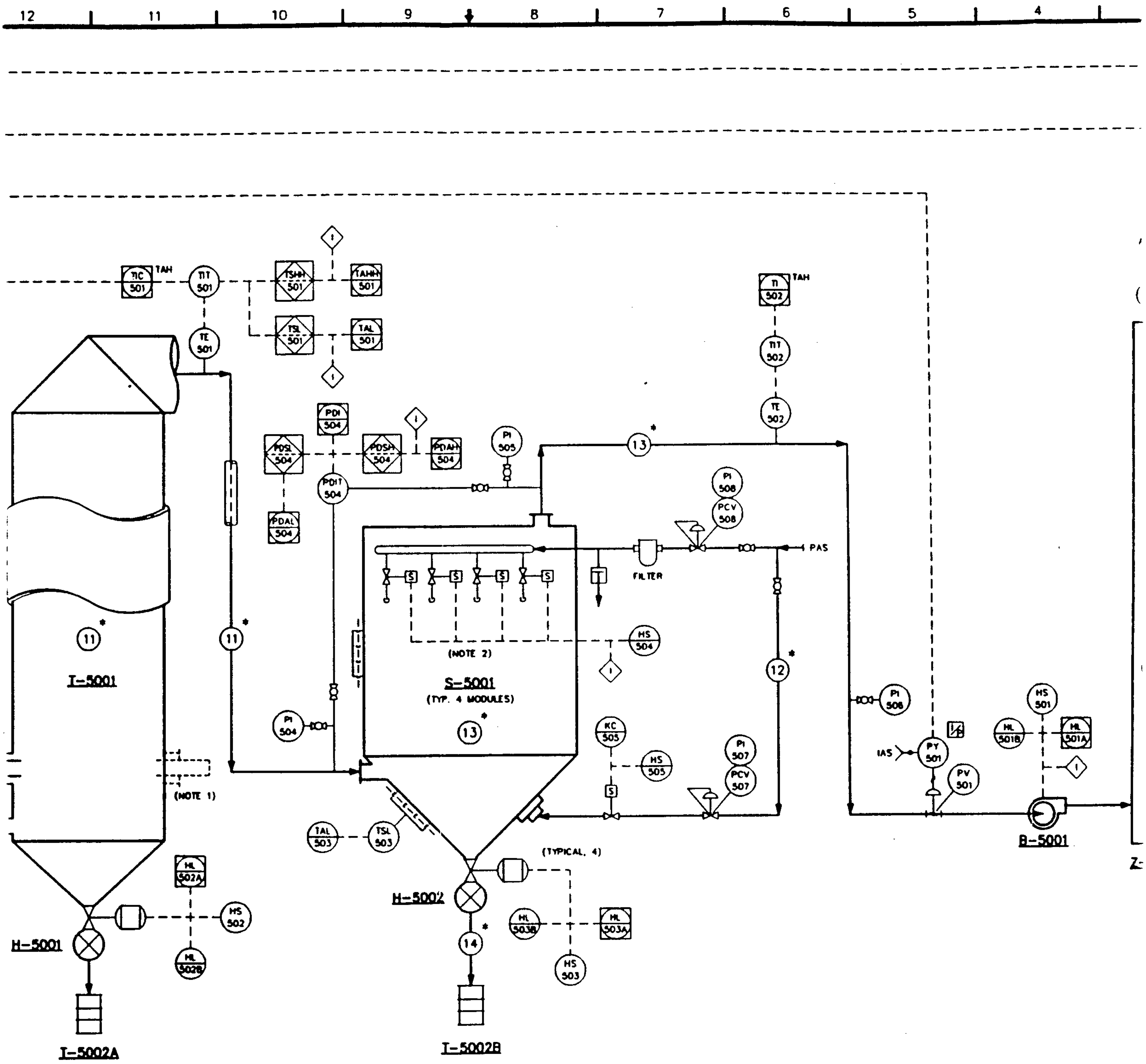


32224308 01/18/93 1:24pm JMH

NOTES

1. OPTIONAL WATER SPRAY NOZZLE
2. BAGS WILL BE LIME COATED
3. FY-503 CALCULATES THE ACTUAL FLOW IN CBC. FIC-501 CONTROLS SECONDARY AIR TO MAINTAIN A SET CBC FLOW RATE
4. * LINE NUMBERS USED FOR HAZOP ANALYSIS

①



H-5001
ROTARY AIRLOCK

T-5002A,B
DUST COLLECTION DRUMS

S-5001
BAGHOUSE

H-5002
ROTARY AIRLOCK

B-5001
INDUCED DRAFT FAN

Z-5001
STACK

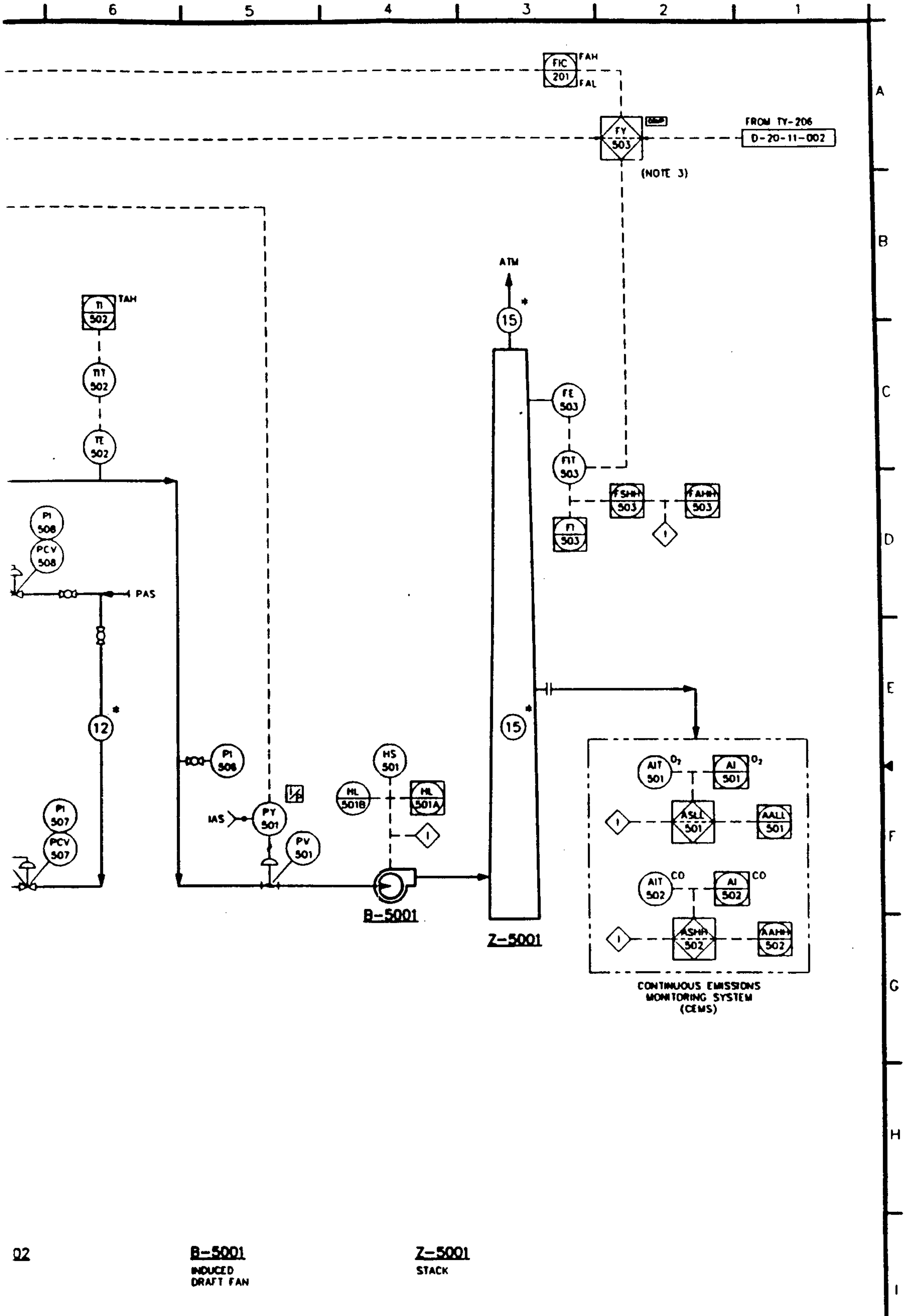
NO	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR
A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	JWH	PA	WMS	PO	PA	

STARTING DATE 9/12/94 | ORIGINATOR WMS | CHKD PA | DRAWN JWH | CHKD WMS | PROJECT MGR P. ACHARYA

2

INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee



INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

PROJECT MGR P. ACHARYA

U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

3

AREA 50
PIPING & INSTRUMENTATION DIAGRAM
AIR POLLUTION CONTROL SYSTEM

PROJ. NO.	DRAWING NO.	REV
322243	D-50-11-001	A

8.0 EQUIPMENT LIST

8.0 Equipment List
Circulating Bed Combustor System

Equipment Number	Equipment Name
B-2001	Combustion Air Blower
B-2002	Loop-Seal Purge Air Blower
B-5001	Induced Draft Fan
F-2001	Circulating Bed Combustor (CBC)
G-2001	Start-Up Burner
H-2001	Ash Cooler Conveyor
H-2002	Limestone Feed Hopper
H-2003	Limestone Feed Screw Conveyor
H-2004	Al_2O_3 Feed Hopper
H-2005	Al_2O_3 Feed Screw Conveyor
H-2006	Hoist
H-2007	Limestone Bag Breaker
H-2008	Al_2O_3 Bag Breaker
H-5001	Rotary Air Lock
H-5002	Rotary Air Lock
P-2001	Cooling Water Recirculating Pump
S-2001	Cyclone Separator
S-5001	Baghouse
T-2001	Ash Bin
T-5001	Partial Quench
T-5002 A, B	Dust Collection Drum
X-2001	Distributor Plate
Z-5001	Stack

9.0 EQUIPMENT SPECIFICATIONS

9.0 Equipment Specifications

The equipment specifications are provided for the following major equipment in the following order:

Equipment Number	Equipment Name	Area Name
F-2001	Circulating Bed Combustor	Combustion Module (Area 20)
B-2001	Combustion Air Fan	Combustion Module (Area 20)
G-2001	Start-up Burner	Combustion Module (Area 20)
F-2002	Cyclone Separator	Combustion Module (Area 20)
B-2002	Loop-Seal Purge Air Blower	Combustion Module (Area 20)
H-2004/H-2008	Al_2O_3 Feed Hopper and Bag Breaker	Combustion Module (Area 20)
H-2002/H-2007	Limestone Feed Hopper and Bag Breaker	Combustion Module (Area 20)
H-2006	Hoist	Combustion Module (Area 20)
H-2005	Al_2O_2 Feed Screw Conveyor	Combustion Module (Area 20)
H-2003	Limestone feed screw combustor	Combustion Module (Area 20)
P-2001	Cooling Water Recirculation Pump	Combustion Module (Area 20)
H-2001	Ash Cooler Conveyor	Combustion Module (Area 30)
T-2001	Ash Bin	Combustion Module (Area 30)
T-5001	Partial Quench	Air Pollution Control (APC) Module (Area 50)
S-5001	Baghouse	APC Module (Area 50)
H-5001	Rotary air lock	APC Module (Area 50)
H-5002	Rotary air lock	APC Module (Area 50)
B-5001	Induced Draft Fan	APC Module (Area 50)
Z-5001	Stack	APC Module (Area 50)
T-5002 A/B	Dust Collection Drums	APC Module (Area 50)

I.T. CORPORATION
POLLUTION CONTROL ENGINEERING

COMBUSTION CHAMBER SPECIFICATION

AREA NO:	20
AREA NAME:	CBC
TAG NO.:	F-2001
EQUIPMENT NAME:	CIRCULATING BED COMBUSTOR

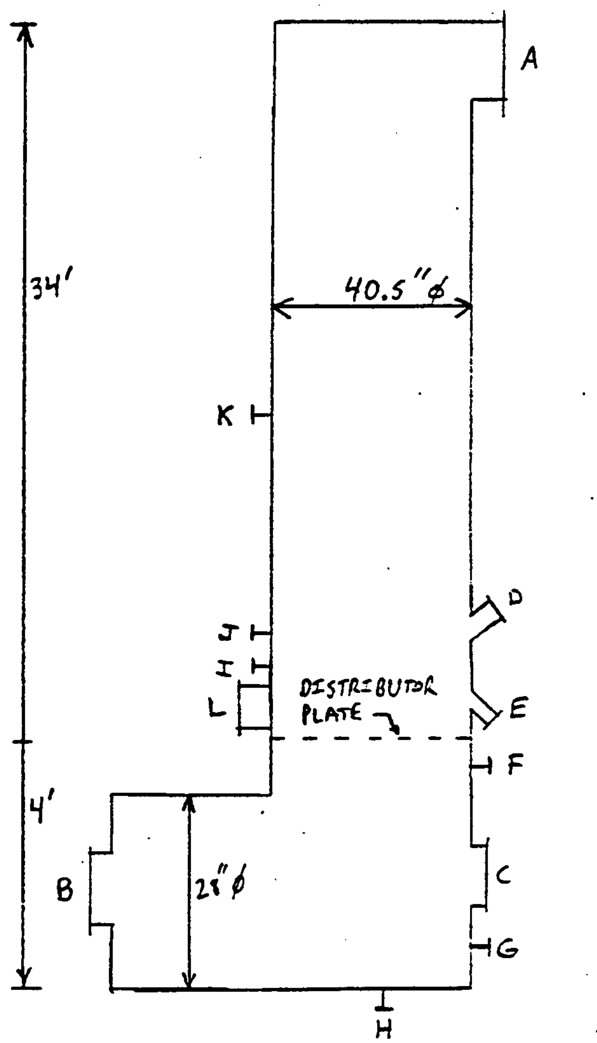
NO	BY	DATE	REV.
1			
2			
3			

IT CORP SPEC. NO.		
SHEET 1 OF 1		
PROJECT NAME USAEC		
JOB NO. 322243		
LOCATION		
BY WMS	APPR PA	DATE 11/30/94

1		Total Volume: Gal.	Field Erected? YES	No. Units: ONE		
2		Operating Pressure, psig	30" W.C. VACUUM			
3		Operating Temperature, deg F	1,600			
4		Operating Shell Temperature, deg.F	350			
5		Design Pressure, psig	60" W.C. VACUUM			
6		Design Temperature, deg F	2,200			
7	D	Design Shell Temperature, deg.F	500			
8	E	Operating Gas Flow	5000 ACFM			
9	S	Operating Gas Residence Time	1.7 SECONDS			
10	I	Bed Material	ALUMINUM OXIDE			
11	G	Bed Charge	1,875 LB			
12	N					
13						
14	D					
15	A	Type Supports:				
16	T	Insulation:	REFRACTORY LINED INTERIOR			
17	A	Fireproooofing:	NONE			
18		Sandblast:	NONE	Paint:		
19		MANHOLE:	Hinged? X	Davited?	Other:	
20		Platform Clips:	Ladder Clips:	Insul. Rings:		
21		Pipe Supports:				
22		Wind Load: 110 MPH mph	Seismic: ZONE 3			
23		Weight Empty: * lbs.	Weight Full of Water: N/A lbs.			
24		Item	Thickness	Mat'l Cls	Mat'l – Minimum Quality	
25		Shell	1/4"	C.S.	A-36	
26	M	Distributor Plate		HAST.	HASTELLOY 276-C	
27	A	Lining	6"	RFRAC.	CASTABLE	
28	T	O.D.	40.5"			
29	E	Length	38 ft			
30	R	Nozzle Necks		C.S.	A-36	
31	I	Flanges		C.S.	A-36	
32	A	Tuyeres		HAST.	HASTELLOY 276-C	
33	L	M.H. Cover		C.S.	A-36	
34	S	Supports				
35		Bolts/Studs				
36		Nuts				
37		Gaskets			HIGH TEMPERATURE	

		Service	Mark	No.	Size	Rating	Face	Type
39	N	OFF-GAS	A	1	28"			
40	O	BURNER	B	1	12"			
41	Z	MANWAY	C	1	18"			
42	Z	LOOP-SEAL	D	1	16"			
43	L	ASH OUTLET	E	1	12"			
44	E	THERMOCOUPLE	F	2	2"			
45		SITE PORT	G	1	4"			
46	S	NATURAL GAS	H	1	1"			
47	C	THERMOCOUPLE	I	1	2"			
48	H	SITE PORT	J	1	4"			
49	E	THERMOCOUPLE	K	1	2"			
50	D	MANWAY	L	1	12"			
51	U		M					
52	L		N					
53	E		O					
54			P					
55		Nozzle to be Plugged or Blinded *						

(Row 38 of the printed form carries the nozzle schedule's column headings.)



For Further Details, See Sheet No.:

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	FAN SPECIFICATION	IT CORP SPEC. NO.
		SHEET 1 OF 1

NO	BY	DATE	REVISION
1			
2			
3			

AREA NO: 20
AREA NAME: CBC
TAG NO.: B-2001
EQUIPMENT NAME: COMBUSTION AIR FAN

PROJECT NAME: USAEC
JOB NO. 322243
LOCATION

BY	APPR	DATE
WMS	PA	11/30/94

GENERAL

Manufacturer: *		Model No.: *	
No. of Units: ONE			
Description of Gas and Materials Handled: AMBIENT AIR			
Flow: 6000 SCFM	S.P. 30 Inches W.G.	Temp.: -20/+110 deg. F	Gas Density: 0.077 Lb/Cu.Ft.
Hours per day operation: 24			
Noise Rating Per Attached Noise Level Spec. No. *			
WHEEL: Diameter: * Inches	Gage and Material of Rims: *		Blades: *
HOUSING GAGE & MATERIALS: Scroll C.S.	Sides C.S.		Tube (Axial) *
Performance Curves: YES	Curve No.: *	Mfr. Size & Type: *	Weight: * Lbs.
R.P.M.: *	B.H.P. Required: *	Mech. Efficiency: *	Outlet Velocity: * ft/sec
BEARINGS: Type: *	Make: *		Manufacturers No.: *
SHAFT: Diameter at Bearings: * inches	Diameter at Wheel: * inches		
Distance Between Bearings: *	Distance from Bearing to Fan Wheel: *		
Maximum Shaft Speed: *			

CNTRFGL

Arrangement: *	Rotation: CCW		Discharge: TH
Single Width? YES	Double Width?	Single Inlet? YES	Double Inlet?
SPECIAL FEATURES REQUIRED: Flanged Inlet and Outlet? YES			Drain in Housing? YES
Clean Out in Housing? YES	Split Housing? NO		Water Jacketed Bearings? NO
Shaft Seals? YES	Inlet or Outlet Dampers? NO		Other: GUARDS & SCREENS

AXIAL

Vertically or Horizontally Mounted?			
Tubeaxial?	Vaneaxial?	Arrangement:	Rotation:
TYPE OF INLET AND OUTLET:	Streamlined Inlet?	Inlet Cone?	Outlet Cone?
SPECIAL FEATURES REQUIRED	Access Doors?	Support Legs?	Motor Hood?
Inlet or Outlet Guard?	Outside Belt Guard?	Flanged Inlet & Outlet?	Other:

PRPLR

Horizontally or Vertically Mounted?		
Direct Drive?	High Capacity Static Conducting V-Belt Drive?	
SPECIAL FEATURES REQUIRED: Safety Guards?	Shutters?	Other:
Description of Guard & Shutter:		
Adjustable Pitch?	Automatic Variable Pitch?	

DRIVER

Furnished By: FAN MFG'R	Elec or Steam Turbine? ELEC	Direct, Gear, Belt or V-Rope? BELT	
ELECTRIC MOTOR:	Mfr.: *	STEAM TURBINE:	Mfr.:
Mounted By: FAN MFG'R	Enclosure: TEFC	Mounted By:	Model:
Speed: * rpm	Service Factor: 1.4	Horsepower: HP	Water Rates: Lbs/Hr
Volts: 460	Temp. Rise:	Speed rpm	Vacuum (if any):
Phase: 3	Insulation:	Inlet Steam Press.:	Inlet Steam Temp.:
Cycles: 60	Frame: *	Normal: psig	Normal: deg. F
Nominal Size: 40 HP	Est. BHP Req'd: 28.4 HP	Max.: psig	Max.: deg F
SPEED REDUCERS:	Mfr.:	Backpressure: psig	
Ratio:	Model:		
Integral or Separate?	Class:		

Nozzles	Size	Rating	Facing	Location
Inlet				
Exhaust				

SEE DRIVER SPECIFICATION NO.:

NOTES

1. FAN SHALL BE SIZED TO OPERATE BETWEEN SEA LEVEL AND 6000 FEET ELEVATION.

VENDOR TO COMPLETE INFORMATION MARKED " * ".

B2001CBC.WK1

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	AIR BURNER	IT CORP SPEC. NO.
		SHEET 1 OF 1

NO	BY	DATE	REVISION
1			
2			
3			

AREA NO:	20
AREA NAME:	CBC
TAG NO.:	G-2001
EQUIPMENT NAME:	START-UP BURNER

PROJECT NAME	JOB NO.	LOCATION
USAEC	322243	

BY	APPR	DATE
WMS	PA	11/30/94

QUANTITY	DESCRIPTION	
1	**Operating Conditions:**	
	Off-gas Temperature	1,300 deg. F
	Combustor Pressure	0 – 30" W.C. Vacuum
	Media	Combustion Gases
	Design Conditions	
	Off-gas Temperature	2,200 deg. F
	Combustor Pressure	−2 to +2 psig
	Wind Load	110 mph
	Earthquake Load	Zone 3
	Ambient Temperature	−20 to 110 deg. F
	Elevation	Sea Level to 6000 ft
	Heat Release	
	Minimum	500,000 Btu/hr
	Maximum	5,000,000 Btu/hr
	Operating	4,000,000 Btu/hr
	Fuel Gas	Natural gas
	No. of Burners and Type	
	Burner	One, vortex type air burner side mounted on the CBC wind box; burner shall extend approximately 5" into the wind box. Turndown shall be 10:1.
	Ignitor	Burner to be ignited by a spark ignitor utilizing an electric spark.
	Material of Construction	Portion of burner in CBC to be 304 SS, or 309 SS, or equal.

I.T. CORPORATION
POLLUTION CONTROL ENGINEERING

CYCLONE SEPARATOR

IT CORP SPEC. NO.

NO	BY	DATE	REV.
1			
2			
3			

SHEET 1 OF 1

PROJECT NAME USAEC

JOB NO. 322243

LOCATION

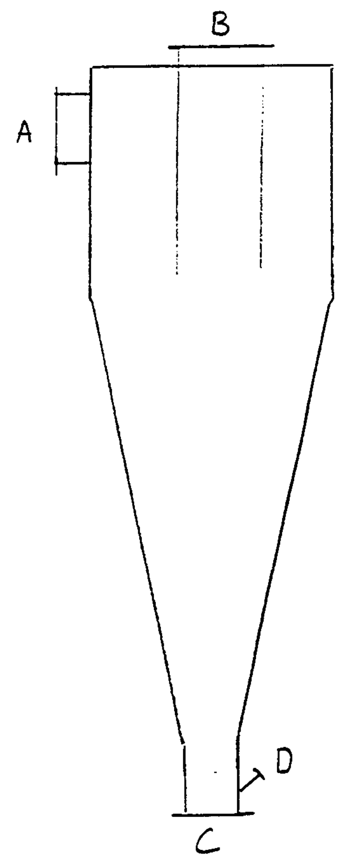
BY	APPR	DATE
WMS	PA	9/13/94

AREA NO: 20
AREA NAME: CBC
TAG NO.: F-2002
EQUIPMENT NAME: CYCLONE SEPARATOR

1		Total Volume: Gal.	Field Erected? YES	No. Units: ONE	
2		Operating Pressure, psig	30" W.C. VACUUM		
3		Operating Temperature, deg F	1,600		
4		Operating Shell Temperature, deg.F	350		
5		Design Pressure, psig	60" W.C. VACUUM		
6		Design Temperature, deg F	2,200		
7	D	Design Shell Temperature, deg.F	500		
8	E	Operating Gas Flow	5000 ACFM		
9	S	Operating/Maximum Inlet Velocity	50 / 70 FT PER SECOND		
10	I	Grain Loading	13 GR/DSCF		
11	G	Differential Pressure	3" to 5" W.C.		
12	N	Removal Efficiency	95% MIN.		
13					
14	D				
15	A	Type Supports:			
16	T	Insulation:	REFRACTORY LINED INTERIOR		
17	A	Fireproooofing:	NONE		
18		Sandblast:	NONE	Paint:	
19		MANHOLE:	Hinged?	Davited?	Other:
20		Platform Clips:	Ladder Clips:		Insul. Rings:
21		Pipe Supports:			
22		Wind Load: 110 MPH mph	Seismic: ZONE 3		
23		Weight Empty: * lbs.	Weight Full of Water: N/A lbs.		

		Item	Thickns	Mat'l Cls	Mat'l – Minimum Quality
24		Item	Thickns	Mat'l Cls	Mat'l – Minimum Quality
25		Shell	1/4"	C.S.	A-36
26	M	Vortex Finder	1/4"	HAST.	HASTELLOY 276-C
27	A	Lining	6"	RFRAC.	CASTABLE
28	T	O.D.	38"		
29	E	Length	120"		
30	R	Nozzle Necks	C.S.		A-36
31	I	Flanges	C.S.		A-36
32	A				
33	L	M.H. Cover			
34	S	Supports			
35		Bolts/Studs			
36		Nuts			
37		Gaskets			HIGH TEMPERATURE

		Service	Mark	No.	Size	Rating	Face	Type
38		Service	Mark	No.	Size	Rating	Face	Type
39	N	OFF-GAS	A	1	28"			
40	O	OFF-GAS	B	1	28"			
41	Z	SOLIDS OUTLET	C	1	16"			
42	Z	POKE-HOLES	D	2	4"			
43	L		E					
44	E		F					
45			G					
46	S		H					
47	C		I					
48	H		J					
49	E		K					
50	D		L					
51	U		M					
52	L		N					
53	E		O					
54			P					
55		Nozzle to be Plugged or Blinded *						



For Further Details, See Sheet No.:

F2002CBC.WK1

I.T. CORPORATION
POLLUTION CONTROL ENGINEERING

FAN SPECIFICATION

IT CORP SPEC. NO.	
SHEET 1	OF 1
PROJECT NAME	USAEC
JOB NO.	322243
LOCATION	

BY	APPR	DATE
WMS	PA	11/30/94

NO	BY	DATE	REVISION
1			
2			
3			

AREA NO:	20
AREA NAME:	CBC
TAG NO.:	B-2002
EQUIPMENT NAME:	LOOP-SEAL PURGE AIR BLOWER

1		Manufacturer: *	Model No.: *		
2		No. of Units: ONE			
3		Description of Gas and Materials Handled: AMBIENT AIR			
4		Flow: 200 SCFM	S.P. 30 Inches W.G.	Temp.: −20/+110 deg. F	Gas Density: 0.077 Lb/Cu.Ft.
5	G	Hours per day operation: 24			
6	E	Noise Rating Per Attached Noise Level Spec. No. *			
7	N	WHEEL: Diameter: * Inches	Gage and Material of Rims: *	Blades: *	
8	E	HOUSING GAGE & MATERIALS: Scroll C.S.	Sides C.S.	Tube (Axial) *	
9	R	Performance Curves: YES	Curve No.: *	Mfr. Size & Type: *	Weight: * Lbs.
10	A	R.P.M.: *	B.H.P. Required: *	Mech. Efficiency: *	Outlet Velocity: * ft/sec
11	L	BEARINGS: Type: *	Make: *	Manufacturers No.: *	
12		SHAFT: Diameter at Bearings: * inches	Diameter at Wheel: * inches		
13		Distance Between Bearings: *	Distance from Bearing to Fan Wheel: *		
14		Maximum Shaft Speed: *			
15					
16	C	Arrangement: *	Rotation: CCW	Discharge: TH	
17	N	Single Width? YES	Double Width?	Single Inlet? YES	Double Inlet?
18	T	SPECIAL FEATURES REQUIRED: Flanged Inlet and Outlet? YES	Drain in Housing? YES		
19	R	Clean Out in Housing? YES	Split Housing? NO	Water Jacketed Bearings? NO	
20	F	Shaft Seals? YES	Inlet or Outlet Dampers? NO	Other: GUARDS & SCREENS	
21	G				
22	L				
23		Vertically or Horizontally Mounted?			
24	A	Tubeaxial?	Vaneaxial?	Arrangement:	Rotation:
25	X	TYPE OF INLET AND OUTLET: Streamlined Inlet?	Inlet Cone?	Outlet Cone?	
26	I	SPECIAL FEATURES REQUIRED Access Doors?	Support Legs?	Motor Hood?	
27	A	Inlet or Outlet Guard?	Outside Belt Guard?	Flanged Inlet & Outlet?	Other:
28	L				
29					
30	P	Horizontally or Vertically Mounted?			
31	R	Direct Drive?	High Capacity Static Conducting V-Belt Drive?		
32	P	SPECIAL FEATURES REQUIRED: Safety Guards?	Shutters?	Other:	
33	L	Description of Guard & Shutter:			
34	R	Adjustable Pitch?	Automatic Variable Pitch?		
35					
36		Furnished By: FAN MFG'R	Elec or Steam Turbine? ELEC	Direct, Gear, Belt or V-Rope? BELT	
37		ELECTRIC MOTOR:	Mfr.: *	STEAM TURBINE:	Mfr.:
38		Mounted By: FAN MFG'R	Enclosure: TEFC	Mounted By:	Model:
39	D	Speed: * rpm	Service Factor: 1	Horsepower: HP	Water Rates: Lbs/Hr
40	R	Volts: 460	Temp. Rise:	Speed rpm	Vacuum (if any):
41	I	Phase: 3	Insulation:	Inlet Steam Press.:	Inlet Steam Temp.:
42	V	Cycles: 60	Frame: *	Normal: psig	Normal: deg. F
43	E	Nominal Size: 3 HP	Est. BHP Req'd: 0.9 HP	Max.: psig	Max.: deg F
44	R	SPEED REDUCERS:	Mfr.:	Backpressure: psig	
45		Ratio:	Model:	Nozzles / Size / Rating / Facing / Location	
46		Integral or Separate?	Class:	Inlet	
47				Exhaust	
48		SEE DRIVER SPECIFICATION NO.:			
49		1. FAN SHALL BE SIZED TO OPERATE BETWEEN SEA LEVEL AND 6000 FEET ELEVATION.			
50	N				
51	O				
52	T				
53	E				
54	S				
55		VENDOR TO COMPLETE INFORMATION MARKED " * ".			

B2002CBC.WK1

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	FEED HOPPER SPECIFICATION			IT CORP SPEC. NO.		
	NO	BY	DATE	REV.	SHEET 1 OF 1	
	1				PROJECT NAME USAEC	
AREA NO: 20 AREA NAME: CBC TAG NO.: H−2004 / H−2008 EQUIPMENT NAME: Al2O3 FEED HOPPER AND BAG BREAKER	2				JOB NO. 322243	
					EXISTING OR NEW? NEW	
	3				BY: SLM	APPR: PA	DATE: 10/1/94

FUNCTIONAL DATA

Application:	Feeding Aluminum Oxide		
Material Handled:	Al2O3		
Density:	70 − 80 pcf		
Material Temperature:	Ambient		
Normal −	Ambient		
Maximum −	110 deg. F.		
Capacity:			
Normal −	50 lb/hr	Particle Size:	1/32"
Range −	10 to 150 lb/hr	Moisture:	none
Fed By:	Manually (bags broken)	Discharge To:	H−2005 Al2O3 Feed Conveyor
Operations, Hrs/Day:	12 − 24	Days/Year:	365
Location:	Outdoors or in temperary bldg.		

SPECIFICATIONS

150 lbs/hr

3' x 3' x 3'
sloped walls.

Material of Construction, 1/4" A−36 steel.

Support, structural steel for independent supporting Feed Hopper & Mass Flow Feeder.

Vendor to include Bag Breaker System (H−2008) and fugative emissions collection system.

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	FEED HOPPER **SPECIFICATION**			IT CORP SPEC. NO.		
	NO	BY	DATE	REV.	SHEET 1 OF 1		
	1				PROJECT NAME **USAEC**		
AREA NO: 20 AREA NAME: CBC TAG NO.: H-2002 / H-2007 EQUIPMENT NAME: LIMESTONE FEED HOPPER AND BAG BREAKER	2				JOB NO. **322243**		
					EXISTING OR NEW? **NEW**		
	3				BY SLM	APPR PA	DATE 11/30/94

FUNCTIONAL DATA

Application:	Feeding Limestone		
Material Handled:	Limestone		
Density:	85 – 95 pcf		
Material Temperature:	Ambient		
Normal –	Ambient		
Maximum –	110 deg. F.		
Capacity:			
Normal –	30 lb/hr	Particle Size:	1/4"
Range –	10 to 150 lb/hr	Moisture:	none
Fed By:	Manually (bags broken)	Discharge To:	H–2003 Limestone Feed Conveyor
Operations, Hrs/Day:	12 – 24	Days/Year:	365
Location:	Outdoors or in temperary bldg.		

SPECIFICATIONS

150 lbs/hr

3' x 3' x 3'
sloped walls.

Material of Construction, 1/4" A–36 steel.

Support, structural steel for independent supporting Feed Hopper & Mass Flow Feeder.

Vendor to include Bag Breaker System (H–2007) and fugative emissions collection system.

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	HOIST SPECIFICATION			IT CORP SPEC. NO.		
	NO	BY	DATE	REV.	SHEET 1 OF 1	
	1				PROJECT NAME USAEC	
AREA NO: 20 AREA NAME: CBC TAG NO.: H-2006 EQUIPMENT NAME: HOIST	2				JOB NO. 322243	
					EXISTING OR NEW? NEW	
	3				BY SLM	APPR PA	DATE 10/1/94

FUNCTIONAL DATA

Application: Lifting Feed Bags and Misc. Jobs
Material Handled: Limestone and Al2O3
Material Temperature: Ambient
Normal – Ambient
Maximum – 110 deg. F.
Capacity:
Normal – Varies
Range – Up to 5 Tons
Loaded By: Manually Discharge To: Platforms
Operations, Hrs/Day: Days/Year:
Location: Outdoors or in temperary bldg.
Cable: 38 ft. steel

SPECIFICATIONS

5 Ton Hoist

Hoist Moves in the x,y, and z plains.

Support, structural steel for independently supporting Hoist.

Motorized for every direction

I.T. CORPORATION
POLLUTION CONTROL ENGINEERING

CONVEYOR SPECIFICATION

IT CORP SPEC. NO.		
SHEET 1 OF 1		
PROJECT NAME USAEC		
JOB NO. 322243		
LOCATION		
BY WMS	APPR PA	DATE 11/30/94

NO	BY	DATE	REV.
1			
2			
3			

AREA NO: 20
AREA NAME: CBC
TAG NO.: H-2005
EQUIPMENT NAME: Al2O3 FEED SCREW CONVEYOR

No.	Section		
1			Quantity: ONE
2	C	S	Material Conveyed: ALUMINUM OXIDE (Al2O3) | Material Form: Sludge Solid X Other:
3	O	E	Density: 70 – 80 lb/ft3 | Temperature: AMB. deg F | Viscosity: cp | Particle Size: Max. 1/32 Inches – Min. Inches
4	N	R	Moisture Content: Dry X Wet % | Free Liquid: Yes No X %
5	D	V	Material Reactions: NONE Hardens Calcifies Other:
6	I	I	Corrosion or Erossion Factors: MODERATELY EROSSIVE
7	T	C	Vapor Formation: Yes No X | Vapor Collection: Yes No X | Vapors Formed:
8	I	E	Service Location: Indoors X Outdoors X
9	O		Location Description:
10	N	O	Capacity: Normal: 50 lb/hr; Maximum: 150 lb/hr | Elevation Gain: 0 ft. | Horizontal Conveyance: * ft.
11	S	P	Operating Factor: hrs/day, days/yr
12		R	Fed by: Al2O3 FEED HOPPER H-2004 | Discharge to: CIRCULATING BED COMBUSTOR F-2001
13		T	Equipment Operation: Continuous X Intermittent On Demand Reversing Other: VARIABLE SPEED
14		N	Past Experience:
15		G	
16	C		Conveyor Type: Belt Roller Pan Apron Drag Flight Other: SCREW TYPE
17	O		Width: * Inches | Length: 4 ft.
18	N		Speed: * ft./min. | Incline /Decline ; Degrees from Horizontal
19	S		Weight: * lbs | Loaded Weight: * lbs
20	T		Enclosure: Open Covered X Sealed X Inert Atmosphere Other:
21	R		Enclosure Seal: HIGH TEMPERATURE GASKET
22	U		BELT CONVEYOR
23	C		Support Type: Idler Roller Flat Plate Other:
24	T		Idler/Plate Arrangement: Flat Troughed | Trough Incline: Degrees
25	I		Roller Size: Inches | Roller Spacing: Inches | Impact Roller Size: Inches | Impact Roller Spacing: Inches
26	O		Head Pulley Length: Inches | Head Pulley Diameter: Inches
27	N		Tail Pulley Length: Inches | Tail Pulley Diameter: Inches
28			Belt Type: | Belt Chevrons: Type:
29			Belt Cleaner: Type: Scraper Brush Wire Other:
30			Skirt Plate: Yes No | Skirt Depth: Inches | Skirt Width: Inches
31	D		CONTINUOUS FLOW CONVEYOR
32	E		Chain Type: | Chain Pitch: Inches
33	T		Pan Type:
34	A		Bearing Spacing: * Inches | Bearing Type: *
35	I		Pan Width: Inches | Pan Depth: Inches | Pan Thickness: Inches
36	L		Attachment to Chain:
37	S		Roller Diameter: Inches | Roller Type:
38			Headshaft Diameter: Inches | Type Sprocket
39			Tailshaft Diameter: Inches | Type Sprocket
40			Flite Pitch: *
41	M		Belt/Pan: | Rollers:
42	A		Idlers: | Scraper:
43	T		Flites: CARBON STEEL | Enclosure: CARBON STEEL
44	'		Shaft: SCH. 80 PIPE, CARBON STEEL | Sprocket:
45	L		Screw: CARBON STEEL | Trough: CARBON STEEL
46	D		Type: Direct Gear V-Belt X Other: | Frame: *
47	R		Electric Motor Make: * | Mounted By: VENDOR | Enclosure: TEFC
48	I		Insulation: | Temp. Rise: deg F | Volts: 460 | Phase: 3 | Cycle: 60
49	V		Estimated BHP Required: * hp | Nominal Motor Size: * hp | Speed: 1800 rpm
50	E		Speed Reducer: Integral Separate * | Ratio: * | Mfr: *
51	R		Model: * | Class:
52			
53			CONVEYOR TO BE EQUIPPED WITH A VARIABLE SPEED DRIVE.
54	M		Shop Tests Required: *
55	I		Mechanical Drawing No's: *
56	S		Other:
57	C		
58			
59			
60			
61			VENDOR TO COMPLETE INFORMATION MARKED *

H2005CBC.WK1

I.T. CORPORATION
POLLUTION CONTROL ENGINEERING

CONVEYOR SPECIFICATION

IT CORP SPEC. NO.	
SHEET 1 OF 1	
PROJECT NAME	USAEC
JOB NO.	322243
LOCATION	

BY	APPR	DATE
WMS	PA	11/30/94

NO	BY	DATE	REV.
1			
2			
3			

AREA NO: 20
AREA NAME: CBC
TAG NO.: H-2003
EQUIPMENT NAME: LIMESTONE FEED SCREW CONVEYOR

No.	Section	Sub	Content
1			Quantity: ONE
2	C	S	Material Conveyed: LIMESTONE | Material Form: Sludge Solid X Other:
3	O	E	Density: 85 – 95 lb/ft3 Temperature: AMB. deg F | Viscosity: cp | Particle Size: Max. 1/32 Inches – Min. Inches
4	N	R	Moisture Content: Dry X Wet % | Free Liquid: Yes No X %
5	D	V	Material Reactions: NONE Hardens Calcifies Other:
6	I	I	Corrosion or Erossion Factors: MODERATELY EROSSIVE
7	T	C	Vapor Formation: Yes No X | Vapor Collection: Yes No X | Vapors Formed:
8	I	E	Service Location: Indoors X Outdoors X
9	O		Location Description:
10	N	O	Capacity: Normal: 50 lb/hr; Maximum: 150 lb/hr | Elevation Gain: 0 ft. | Horizontal Conveyance: * ft.
11	S	P	Operating Factor: hrs/day, days/yr
12		R	Fed by: LIMESTONE FEED HOPPER H-2002 | Discharge to: CIRCULATING BED COMBUSTOR F-2001
13		T	Equipment Operation: Continuous X Intermittent On Demand Reversing Other: VARIABLE SPEED
14		N	Past Experience:
15		G	
16	C		Conveyor Type: Belt Roller Pan Apron Drag Flight Other: SCREW TYPE
17	O		Width: * Inches | Length: 4 ft.
18	N		Speed: * ft./min. | Incline /Decline ; Degrees from Horizontal
19	S		Weight: * lbs | Loaded Weight: * lbs
20	T		Enclosure: Open Covered X Sealed X Inert Atmosphere Other:
21	R		Enclosure Seal: HIGH TEMPERATURE GASKET
22	U		BELT CONVEYOR
23	C		Support Type: Idler Roller Flat Plate Other:
24	T		Idler/Plate Arrangement: Flat Troughed | Trough Incline: Degrees
25	I		Roller Size: Inches | Roller Spacing: Inches | Impact Roller Size: Inches | Impact Roller Spacing: Inches
26	O		Head Pulley Length: Inches | Head Pulley Diameter: Inches
27	N		Tail Pulley Length: Inches | Tail Pulley Diameter: Inches
28			Belt Type: | Belt Chevrons: Type:
29			Belt Cleaner: Type: Scraper Brush Wire Other:
30			Skirt Plate: Yes No | Skirt Depth: Inches | Skirt Width: Inches
31	D		CONTINUOUS FLOW CONVEYOR
32	E		Chain Type: | Chain Pitch: Inches
33	T		Pan Type:
34	A		Bearing Spacing: * Inches | Bearing Type: *
35	I		Pan Width: Inches | Pan Depth: Inches | Pan Thickness: Inches
36	L		Attachment to Chain:
37	S		Roller Diameter: Inches | Roller Type:
38			Headshaft Diameter: Inches | Type Sprocket
39			Tailshaft Diameter: Inches | Type Sprocket
40			Flite Pitch: *
41	M		Belt/Pan: | Rollers:
42	A		Idlers: | Scraper:
43	T		Flites: CARBON STEEL | Enclosure: CARBON STEEL
44	'		Shaft: SCH. 80 PIPE, CARBON STEEL | Sprocket:
45	L		Screw: CARBON STEEL | Trough: CARBON STEEL
46	D		Type: Direct Gear V-Belt X Other: | Frame: *
47	R		Electric Motor Make: * | Mounted By: VENDOR | Enclosure: TEFC
48	I		Insulation: | Temp. Rise: deg F | Volts: 460 Phase: 3 | Cycle: 60
49	V		Estimated BHP Required: * hp | Nominal Motor Size: * hp | Speed: 1800 rpm
50	E		Speed Reducer: Integral Separate * | Ratio: * | Mfr: *
51	R		Model: * | Class:
52			
53			CONVEYOR TO BE EQUIPPED WITH A VARIABLE SPEED DRIVE.
54	M		Shop Tests Required: *
55	I		Mechanical Drawing No's: *
56	S		Other:
57	C		
58			
59			
60			
61			VENDOR TO COMPLETE INFORMATION MARKED *

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	# PUMP SPECIFICATION	IT CORP SPEC. NO.

NO	BY	DATE	REV.
1			
2			
3			

SHEET 1 OF 1		
PROJECT NAME USAEC		
JOB NO. 322243		
EXISTING OR NEW? NEW		
BY WMS	APPR PA	DATE 11/30/94

AREA NO: 20
AREA NAME: CBC
TAG NO.: P-2001
EQUIPMENT NAME: COOLING WATER RECIRCULATION PUMP

1	C	Manufacturer: *		Model No.: *	
2	O	No. of Units: ONE			
3	N	Liquid Pumped: WATER		Max. Capacity at P.T.: 50 gpm	Discharge Press.: 103 ft.
4	D	Pumping Temp.: 150 deg F	Sp. Gr. @ P.T.: 1.0	Suction Press psia	Viscosity @ P.T.: 1 cP
5	T	Differential Press.: psi	Differential Head: Ft.	Vapor Pressure @ P.T.: psia	NPSH Available: ft.
6	N	Corrosion or Errosion Factors:			NPSH Required: * ft.
7	S				

8		Horizontal or Vertical Arrangement? HORIZONTAL					Single or Double Suction? SINGLE	
9	C	CW OR CCW Direction of Rotation Facing Pump Coupling: CW					Case Design Press.: * psig	Max. Allow. W.P.: * psig
10	O	Number of Stages:	Speed: * rpm				Shut-off Press.: feet	Vol. Eff. @ Rating: * %
11	N	Barrel:	Split?				Horizontal? HORIZONTAL	Vertical?
12	S	Impeller:	Type:				Max. Diameter: *	Min. Diameter: * Inches
13	T	Actual Imp. Dia.: * Inch	Vent and Drain Tapped?				Thrust Bearing Type:	Radial Bearing Type:
14	R	Nozzles	Size	Rating	Facing	Location	Bearing Lub. Type:	
15	U	Suction	*	150#	FF	END	Oiler? *	Oiler Type: *
16	C	Discharge	*	150#	FF	TOP	Coupling Mfr.:	Coupling Model:
17	T	Vents					Baseplate? YES	Type Baseplate: INTEGRAL
18	I	Drains	*	UNC		BOTTOM	Water Cooling: Csng, Stffg Bx, Brgs, Pdstl, Glnd or none? *	
19	O	Cooling H2O					Total Water Req'd: * gpm	Smothering Gland? *
20	N	Stuffing Box Lubrication: Oil, Grease or None? *					Type Packing: *	Seal Oil Connection? *
21		MECHANICAL SEAL:	Furnished By: *				Manufacturer: *	Type: *
22	D	Single or Double? *	Inside or Outside?				Balanced or Unbalanced?	
23	E	Rotary Unit:	Seal Ring Mtrl:				Face Material:	Shaft Packing: *
24	T	Insert:	Reversible?				Face Material:	
25	A	Insert Mounting: Clamped, O-Ring or Press Fit?						
26	I	Gland:	Plain?				Carbon Throttle Bushing?	
27	L	Gland Stuffing Box Machined & Tapped for:					Dead End Lub.?	Circulating Lub.?
28	S	Flushing Seal Faces with Discharge Bypass?					Quenching?	Vent & Drain?
29		Flushing Seal Faces with External Fluid?					Auxiliary Stuffing Box Required?	
30		Weight of Pump: * lbs.	Weight of Base: * lbs.				Weight of Driver: * lbs.	Shipping Weight: lbs.

31	M	Casing & Covers: CAST IRON	Shaft:	Casing wear Rings: *	Shaft Sleeves: *
32	T	Impeller: *	Lantern Rings: *	Impeller Wear Rings:	Stuffing Box Bushings:
33	L	Glands: *	Gaskets:		

34		Furnished By: PUMP MGFR	Elec. or Steam Turbine? ELEC	Direct, Gear, V-Belt or Rope? V-BELT					
35		ELECTRIC MOTOR:	Mfr.: *	STEAM TURBINE:			Mfr.:		
36		Mounted By: PUMP MGFR	Enclosure: TEFC	Mounted By:			Model:		
37	D	Speed: 1800 rpm	Service Factor: 1.15	Horsepower: HP			Water Rates: Lbs/Hr		
38	R	Volts: 460	Temp. Rise:	Speed rpm			Vacuum (if any):		
39	I	Phase: 3	Insulation:	Inlet Steam Press.:			Inlet Steam Temp.:		
40	V	Cycles: 60 -	Frame: *	Normal: psig			Normal: deg. F		
41	E	Nominal Size: 5 HP	Est. BHP Req'd: 4.0 HP	Max.: psig			Max.: deg F		
42	R	SPEED REDUCERS:	Mfr.:	Backpressure: psig					
43		Ratio:	Model:	Nozzles	Size	Rating	Facing	Location	
44		Integral or Separate?	Class:	Inlet					
45				Exhaust					
46		See Driver Specification No.:							

47	T	Performance Curve? YES	Certified?	M	Serial Number: *
48	E	Curve No.: *		I	Outline Drawing Number: *
49	S	Hydrotest? YES	Pressure: psig	S	Cross Section Drawing Number: *
50	T	Witness Testing? NO	Shop Inspection? NO	C	

51	N	
52	O	
53	T	
54	E	
55	S	VENDOR TO COMPLETE INFORMATION MARKED *

P2001CBC.WK1

I.T. CORPORATION
POLLUTION CONTROL ENGINEERING

CONVEYOR SPECIFICATION

IT CORP SPEC. NO.

SHEET 1 OF 1

PROJECT NAME: **USAEC**

JOB NO. **322243**

LOCATION

BY	APPR	DATE
WMS	PA	11/30/94

NO	BY	DATE	REV.
1			
2			
3			

AREA NO: 30
AREA NAME: CBC
TAG NO.: H-2001
EQUIPMENT NAME: ASH COOLER CONVEYOR

1			Quantity: **ONE**
2	CONDITIONS	SERVICE	Material Conveyed: **BED MATERIAL, ASH** | Material Form: Sludge Solid **X** Other:
3			Density: **20 – 50** lb/ft3 | Temperature: **1,600** deg F | Viscosity: cp | Particle Size: Max. **1/4** Inches – Min. Inches
4			Moisture Content: Dry **X** Wet % | Free Liquid: Yes No **X** %
5			Material Reactions: **NONE** Hardens Calcifies Other:
6			Corrosion or Erossion Factors: **MODERATELY EROSSIVE**
7			Vapor Formation: Yes No **X** | Vapor Collection: Yes No **X** | Vapors Formed:
8			Service Location: Indoors **X** Outdoors **X**
9			Location Description:
10		OPERATING	Capacity: Normal: **0.30** ton/hr; Maximum: **0.50** ton/hr | Elevation Gain: **4** ft. | Horizontal Conveyance: * ft.
11			Operating Factor: hrs/day, days/yr
12			Fed by: **CIRCULATING BED COMBUSTOR F-2001** | Discharge to: **ASH BIN T-2001**
13			Equipment Operation: Continuous **X** Intermittent On Demand Reversing Other: **VARIABLE SPEED**
14			Past Experience:
15			**SCREW TO SERVE AS CONVEYOR AS WELL AS HEAT EXCHANGER; SOLIDS OUTLET TEMP. 200 deg. F.**
16	CONSTRUCTION DETAILS		Conveyor Type: Belt Roller Pan Apron Drag Flight Other: **WATER COOLED SCREW**
17			Width: * Inches | Length: * ft.
18			Speed: * ft./min. | Incline **X** /Decline ; * Degrees from Horizontal
19			Weight: * lbs | Loaded Weight: * lbs
20			Enclosure: Open Covered **X** Sealed **X** Inert Atmosphere Other:
21			Enclosure Seal: **HIGH TEMPERATURE GASKET**
22			BELT CONVEYOR
23			Support Type: Idler Roller Flat Plate Other:
24			Idler/Plate Arrangement: Flat Troughed | Trough Incline: Degrees
25			Roller Size: Inches | Roller Spacing: Inches | Impact Roller Size: Inches | Impact Roller Spacing: Inches
26			Head Pulley Length: Inches | Head Pulley Diameter: Inches
27			Tail Pulley Length: Inches | Tail Pulley Diameter: Inches
28			Belt Type: | Belt Chevrons: Type:
29			Belt Cleaner: Type: Scraper Brush Wire Other:
30			Skirt Plate: Yes No | Skirt Depth: Inches | Skirt Width: Inches
31			CONTINUOUS FLOW CONVEYOR
32			Chain Type: | Chain Pitch: Inches
33			Pan Type:
34			Bearing Spacing: * Inches | Bearing Type: *
35			Pan Width: Inches | Pan Depth: Inches | Pan Thickness: Inches
36			Attachment to Chain:
37			Roller Diameter: Inches | Roller Type:
38			Headshaft Diameter: Inches | Type Sprocket
39			Tailshaft Diameter: Inches | Type Sprocket
40			Flite Pitch: *
41	MAT'L		Belt/Pan: | Rollers:
42			Idlers: | Scraper:
43			Flites: **CARBON STEEL** | Enclosure: **CARBON STEEL**
44			Shaft: **SCH. 80 PIPE, CARBON STEEL** | Sprocket:
45			Screw: **CARBON STEEL** | Trough: **CARBON STEEL**
46	DRIVER		Type: Direct **X** Gear V-Belt Other: | Frame: *
47			Electric Motor Make: * | Mounted By: **VENDOR** | Enclosure: **TEFC**
48			Insulation: | Temp. Rise: deg F | Volts: **460** Phase: **3** Cycle: **60**
49			Estimated BHP Required: * hp | Nominal Motor Size: **5** hp | Speed: **1800** rpm
50			Speed Reducer: Integral Separate * | Ratio: * | Mfr: *
51			Model: * | Class:
52			
53			**CONVEYOR TO BE EQUIPPED WITH A VARIABLE SPEED DRIVE.**
54	MISC		Shop Tests Required: *
55			Mechanical Drawing No's: *
56			Other:
57			**1. MATERIAL HEAT CAPACITY = 0.25 Btu/lb-deg.F**
58			**2. COOLING WATER: FLOW =** * | **INLET TEMP. =** * | **OUTLET TEMP. =** *
59			**INLET PRESSURE =** * | **PRESSURE DROP =** *
60			
61			VENDOR TO COMPLETE INFORMATION MARKED *

H2001CBC.WK1

I.T. CORPORATION **POLLUTION CONTROL ENGINEERING**	**HOPPER SPECIFICATION**				IT CORP SPEC. NO.
	NO	BY	DATE	REV.	SHEET 1 OF 1
	1				PROJECT NAME **USAEC**
AREA NO: 30 AREA NAME: CBC TAG NO.: T-2001 EQUIPMENT NAME: ASH BIN	2				JOB NO. **322243**
					EXISTING OR NEW? **NEW**
	3				BY: SLM · APPR: PA · DATE: 11/30/94

FUNCTIONAL DATA

Application:	Receiving Hot Ash		
Material Handled:	CBC Bed Material, Ash		
Density:	20 – 50 pcf		
Material Temperature:			
Normal –	200 deg. F		
Maximum –	600 deg. F.		
Capacity:			
Normal –	30 lb/hr	Particle Size:	1" max.
Range –	10 to 150 lb/hr	Moisture:	None
Operations, Hrs/Day:	12 – 24	Days/Year:	365
Location:	Outdoors or in temperary bldg.		

SPECIFICATIONS

1. Bin capacity to be 1 cubic yard.

2. Bin to include tote lugs for transportation.

3. Bin to include hinged inspection lid with entrance port for ash inlet.

4. Materials of construction to be carbon steel.

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	**VERTICAL VESSEL**

NO	BY	DATE	REV.
1			
2			
3			

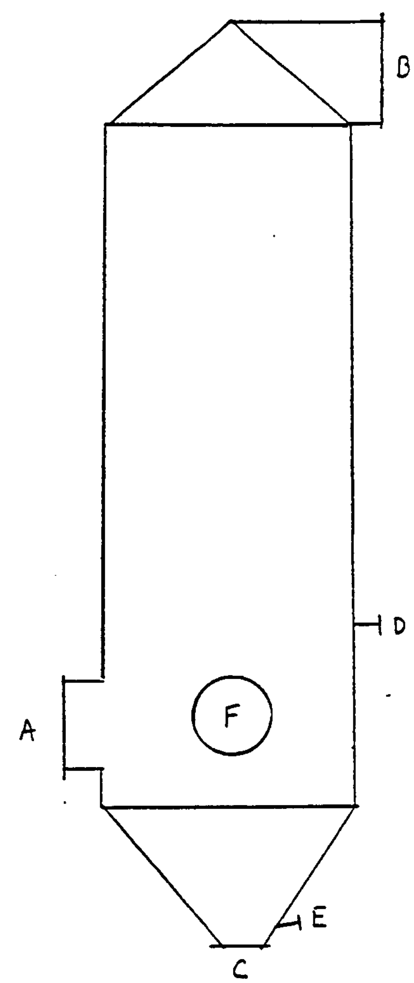
IT CORP SPEC. NO.		
SHEET 1 OF 1		
PROJECT NAME USAEC		
JOB NO. 322243		
LOCATION		
BY WMS	APPR PA	DATE 11/30/94

AREA NO: 50
AREA NAME: APC
TAG NO.: T-5001
EQUIPMENT NAME: PARTIAL QUENCH

1		Total Volume: Gal. | Field Erected?	YES | No. Units: ONE
2		Operating Pressure, psig	30" W.C. VACUUM
3		Inlet Operating Temperature, deg F	1,600
4		Outlet Operating Temperature, deg F	400
5		Design Pressure, psig	60" W.C. VACUUM
6		Design Operating Temperature, deg F	2,200
7	D	Operating Gas Flow	5000 ACFM
8	E	Operating Velocity	10 FT PER SECOND
9	S	Residence Time	3 SECONDS
10	I	No. of Water Guns	2
11	G	Configuration	COCURRENT, UP-FLOW
12	N		
13			
14	D		
15	A	Type Supports:	
16	T	Insulation: EXTERIOR INSULATION	
17	A	Fireprooofing: NONE	
18		Sandblast: NONE	Paint:
19		MANHOLE: Hinged? X | Davited?	Other:
20		Platform Clips: | Ladder Clips:	Insul. Rings:
21		Pipe Supports:	
22		Wind Load: 110 MPH mph	Seismic: ZONE 3
23		Weight Empty: * lbs.	Weight Full of Water: N/A lbs.

		Item	Thickns	Mat'l Cls	Mat'l - Minimum Quality
24		Item	Thickns	Mat'l Cls	Mat'l - Minimum Quality
25		Shell	1/4"	C.S.	A-36
26	M	Heads			
27	A	Lining			
28	T	O.D.	40"		
29	E	Length	33 ft		
30	R	Nozzle Necks		C.S.	A-36
31	I	Flanges		C.S.	A-36
32	A				
33	L	M.H. Cover			
34	S	Supports			
35		Bolts/Studs			
36		Nuts			
37		Gaskets			HIGH TEMPERATURE

		Service	Mark	No.	Size	Rating	Face	Type
38		Service	Mark	No.	Size	Rating	Face	Type
39	N	INLET OFF-GAS	A	1	28"			
40	O	OUTLET OFF-GAS	B	1	18"			
41	Z	SOLIDS OUTLET	C	1	4"			
42	Z	NOZZLES	D	2	4"			
43	L	POKE-HOLES	E	2	4"			
44	E	MANWAY	F	1	18"			
45			G					
46	S		H					
47	C		I					
48	H		J					
49	E		K					
50	D		L					
51	U		M					
52	L		N					
53	E		O					
54			P					
55		Nozzle to be Plugged or Blinded *						



For Further Details, See Sheet No.:

T5001CBC.WK1

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	MISC. SPECIFICATION	IT CORP SPEC. NO.

NO	BY	DATE	REVISION
1			
2			
3			

SHEET 1 OF 1

PROJECT NAME: USAEC

JOB NO.: 322243

LOCATION:

BY	APPR	DATE
WMS	PA	11/30/94

AREA NO:	50
AREA NAME:	APC
TAG NO.:	S-5001
EQUIPMENT NAME:	BAGHOUSE

QUANTITY	DESCRIPTION
1	Process Conditions

<u>Process Conditions</u>

Application:	Gas Cleaning System
Material Handled:	Fine Particulate
Flue gas Flow:	3500 ACFM
Flue Gas Pressure:	Operating: 35" W.C. vacuum; Design: 60" W.C. vacuum
Flue Gas Temperature:	400 to 450 deg. F
Flue Gas Moisture:	50% by volume
Inlet Particulate Loading:	79 lb per hour
Outlet Particulate Loading:	Less than or equal to 0.01 gr/dscf @ 7% oxygen

<u>Specifications:</u>

Air/cloth Ratio:	3:1
Number of Modules:	Four
Cleaning Method:	Pulse jet (on-line cleaning)
Maximum Pressure Drop:	6" W.C.
Materials of Construction:	– A-36 carbon steel housing/reinforcement supports – Galvanized steel mesh bag cages – Woven fiberglass bags.
Approximate Dimensions:	13 ft x 17ft x 26 ft high (includes 4 ft bottom clearance)

<u>Miscellaneous</u>

- System including module main housing, top lid assemply with tube sheet for bag support, structural support and access platform, manifolds and inlet dampers between modules.

- Include C.S. hoppers, inlet vane baffle, access doors, level indicators, poke holes, vibrators, hopper heaters, and strike plates.

- Baghouse to be fully insulated (2 inches minimum).

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	MISC. SPECIFICATION				IT CORP SPEC. NO.		
	NO	BY	DATE	REVISION	SHEET 1 OF 1		
	1				PROJECT NAME USAEC		
AREA NO: 50 AREA NAME: APC TAG NO.: H-5001 EQUIPMENT NAME: ROTARY AIRLOCK	2				JOB NO. 322243		
					LOCATION		
	3				BY WMS	APPR PA	DATE 11/30/94

QUANTITY	DESCRIPTION
1	FUNCTION DATA

Application:	Processing Gas Cleaning System Dust
Material Handled:	Fine Particulate
Density:	20 to 50 lb per cubic foot
Material Temperature:	500 to 700 deg. F
Moisture:	No Moisture
Capacity:	Average: 10 lb/hr; Design: 100 lb/hr
Fed By:	Partial Quench T-5001
Operation:	24 hours per day
Location:	Outdoors or Indoors

Specifications:

- 1/3 HP motor, 1.15 safety factor, 460V, 3 phase, 60 hz
- Cast iron body construction
- Closed end rotor, A-36 carbon steel construction
- Supply with plant air shaft purge connections
- To be supplied with a zero speed switch
- Body and side plate ports to facilitate cleanout with compressed air

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	MISC. SPECIFICATION			IT CORP SPEC. NO.
	NO	BY	DATE	REVISION
	1			
AREA NO: 50 AREA NAME: APC TAG NO.: H-5002 EQUIPMENT NAME: ROTARY AIRLOCK	2			
	3			

SHEET	1 OF 1
PROJECT NAME	USAEC
JOB NO.	322243
LOCATION	

BY	APPR	DATE
WMS	PA	11/30/94

QUANTITY	DESCRIPTION
1	FUNCTION DATA

Application:	Processing Gas Cleaning System Dust
Material Handled:	Fine Particulate
Density:	20 to 50 lb per cubic foot
Material Temperature:	300 to 500 deg. F
Moisture:	No Moisture
Capacity:	Average: 70 lb/hr; Maximum: 100 lb/hr
Fed By:	Baghouse S-5001
Operation:	24 hours per day
Location:	Outdoors or Indoors

Specifications:

- 1/3 HP motor, 1.15 safety factor, 460V, 3 phase, 60 hz
- Cast iron body construction
- Closed end rotor, A-36 carbon steel construction
- Supply with plant air shaft purge connections
- To be supplied with a zero speed switch
- Body and side plate ports to facilitate cleanout with compressed air

I.T. CORPORATION **POLLUTION CONTROL ENGINEERING**	
AREA NO:	50
AREA NAME:	APC
TAG NO.:	B–5001
EQUIPMENT NAME:	INDUCED DRAFT FAN

FAN SPECIFICATION

NO	BY	DATE	REVISION
1			
2			
3			

IT CORP SPEC. NO.	
SHEET 1 OF 1	
PROJECT NAME	USAEC
JOB NO.	322243
LOCATION	NEW
BY: WMS	APPR: PA
DATE	11/30/94

1		Manufacturer: *	Model No.: *					
2		No. of Units: ONE						
3		Description of Gas and Materials Handled: COMBUSTION GAS OR AMBIENT AIR						
4		Flow: 6000 ACFM	S.P. 60 Inches W.G.	Temp.: 60 – 450 deg. F	Gas Density: NOTE 2 Lb/Cu.Ft.			
5	G	Hours per day operation: 24						
6	E	Noise Rating Per Attached Noise Level Spec. No. *						
7	N	WHEEL: Diameter: * Inches	Gage and Material of Rims: *	Blades: *				
8	E	HOUSING GAGE & MATERIALS: Scroll C.S.	Sides C.S.	Tube (Axial) *				
9	R	Performance Curves: YES	Curve No.: *	Mfr. Size & Type: *	Weight: * Lbs.			
10	A	R.P.M.: *	B.H.P. Required: *	Mech. Efficiency: *	Outlet Velocity: * ft/sec			
11	L	BEARINGS: Type: *	Make: *	Manufacturers No.: *				
12		SHAFT: Diameter at Bearings: * inches	Diameter at Wheel: * inches					
13		Distance Between Bearings: *	Distance from Bearing to Fan Wheel: *					
14		Maximum Shaft Speed: *						
15								
16	C	Arrangement: *	Rotation: CW	Discharge: BAU				
17	N	Single Width? YES	Double Width?	Single Inlet? YES	Double Inlet?			
18	T	SPECIAL FEATURES REQUIRED: Flanged Inlet and Outlet? YES	Drain in Housing? YES					
19	R	Clean Out in Housing? YES	Split Housing? NO	Water Jacketed Bearings? NO				
20	F	Shaft Seals? YES	Inlet or Outlet Dampers? INLET	Other: GUARDS & SCREENS				
21	G							
22	L							
23		Vertically or Horizontally Mounted?						
24	A	Tubeaxial?	Vaneaxial?	Arrangement:	Rotation:			
25	X	TYPE OF INLET AND OUTLET:	Streamlined Inlet?	Inlet Cone?	Outlet Cone?			
26	I	SPECIAL FEATURES REQUIRED	Access Doors?	Support Legs?	Motor Hood?			
27	A	Inlet or Outlet Guard?	Outside Belt Guard?	Flanged Inlet & Outlet?	Other:			
28	L							
29								
30	P	Horizontally or Vertically Mounted?						
31	R	Direct Drive?	High Capacity Static Conducting V–Belt Drive?					
32	P	SPECIAL FEATURES REQUIRED: Safety Guards?	Shutters?	Other:				
33	L	Description of Guard & Shutter:						
34	R	Adjustable Pitch?	Automatic Variable Pitch?					
35								
36		Furnished By: FAN MFG'R	Elec or Steam Turbine? ELEC	Direct, Gear, Belt or V–Rope? DIRECT				
37		ELECTRIC MOTOR:	Mfr.: *	STEAM TURBINE:	Mfr.:			
38		Mounted By:FAN MFG'R	Enclosure: TEFC	Mounted By:	Model:			
39	D	Speed: * rpm	Service Factor: 1.15	Horsepower: HP	Water Rates: Lbs/Hr			
40	R	Volts: 460	Temp. Rise:	Speed rpm	Vacuum (if any):			
41	I	Phase: 3	Insulation:	Inlet Steam Press.:	Inlet Steam Temp.:			
42	V	Cycles: 60	Frame: *	Normal: psig	Normal: deg. F			
43	E	Nominal Size: 75 HP	Est. BHP Req'd: 56.7 HP	Max.: psig	Max.: deg F			
44	R	SPEED REDUCERS:	Mfr.:	Backpressure: psig				
45		Ratio:	Model:	Nozzles	Size	Rating	Facing	Location
46		Integral or Separate?	Class:	Inlet				
47				Exhaust				
48		SEE DRIVER SPECIFICATION NO.:						
49		1. FAN SHALL BE SIZED TO OPERATE BETWEEN SEA LEVEL AND 6000 FEET ELEVATION.						
50	N	2. GAS DENSITY MAY RANGE FROM 0.04 TO 0.07 LB PER CUBIC FOOT.						
51	O	3. VENDOR TO SUPPLY REMOTELY CONTROLLED VARIABLE INLET VANE DAMPER.						
52	T							
53	E							
54	S							
55		VENDOR TO COMPLETE INFORMATION MARKED " * ".						

B5001CBC.WK1

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	STACK	IT CORP SPEC. NO.

NO	BY	DATE	REV.
1			
2			
3			

SHEET 1 OF 1

PROJECT NAME: USAEC

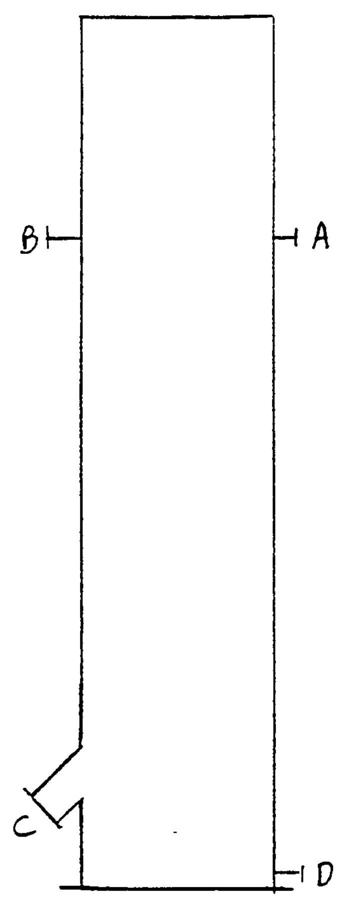
JOB NO. 322243

LOCATION

BY	APPR	DATE
WMS	PA	11/30/94

AREA NO: 50
AREA NAME: APC
TAG NO.: Z-5001
EQUIPMENT NAME: STACK

1		Total Volume: Gal.	Field Erected? YES	No. Units: ONE			
2		Operating Pressure, psig	2-3" W.C. PRESSURE				
3		Operating Temperature, deg F	400				
4		Design Temperature, deg F	500				
5		Operating Gas Flow	3,200 ACFM				
6		Design Gas Flow	5,000 ACFM				
7	D	Design/Operating Velocity	50 FT PER SECOND				
8	E						
9	S						
10	I						
11	G						
12	N						
13							
14	D						
15	A	Type Supports:	SELF STANDING				
16	T	Insulation:	NONE				
17	A	Fireproooofing:	NONE				
18		Sandblast:	NONE	Paint:			
19		MANHOLE:	Hinged?	Davited?	Other:		
20		Platform Clips:	Ladder Clips:	Insul. Rings:			
21		Pipe Supports:					
22		Wind Load: 110 MPH mph	Seismic: ZONE 3				
23		Weight Empty: * lbs.	Weight Full of Water: N/A lbs.				
24		Item	Thicknss	Mat'l Cls	Mat'l – Minimum Quality		
25		Shell	1/4"	C.S.	A-36		
26	M	Heads					
27	A	Lining					
28	T	O.D.	18"				
29	E	Length	62 ft				
30	R	Nozzle Necks	C.S.		A-36		
31	I	Flanges	C.S.		A-36		
32	A						
33	L	M.H. Cover					
34	S	Supports					
35		Bolts/Studs					
36		Nuts					
37		Gaskets					
38		Service	Mark	No.	Size	Rating	Face	Type
39	N	SAMPLE PORT	A	2	4"			
40	O	SAMPLE PORT	B	2	2"			
41	Z	OFF-GAS	C	1	18"			
42	Z	DRAIN	D	1	2"			
43	L		E					
44	E		F					
45			G					
46	S		H					
47	C		I					
48	H		J					
49	E		K					
50	D		L					
51	U		M					
52	L		N					
53	E		O					
54			P					
55		Nozzle to be Plugged or Blinded *						



For Further Details, See Sheet No.:

Z5001CBC.WK1

I.T. CORPORATION POLLUTION CONTROL ENGINEERING	HOPPER SPECIFICATION				IT CORP SPEC. NO.		
	NO	BY	DATE	REV.	SHEET 1 OF 1		
	1				PROJECT NAME USAEC		
AREA NO: 50 AREA NAME: APC TAG NO.: T-5002A,B EQUIPMENT NAME: DUST COLLECTION DRUMS	2				JOB NO. 322243		
					EXISTING OR NEW? NEW		
	3				BY SLM	APPR PA	DATE 11/30/94

FUNCTIONAL DATA

Application: Receiving Hot Ash

Material Handled: Ash, dust

Density: 20 – 50 pcf

Material Temperature:

- Normal – 400 deg. F
- Maximum – 500 deg. F.

Capacity:

- Normal – 1 lb/hr
- Range – 0 to 10 lb/hr

Particle Size: < 1/32"

Moisture: None

Operations, Hrs/Day: 12 – 24

Days/Year: 365

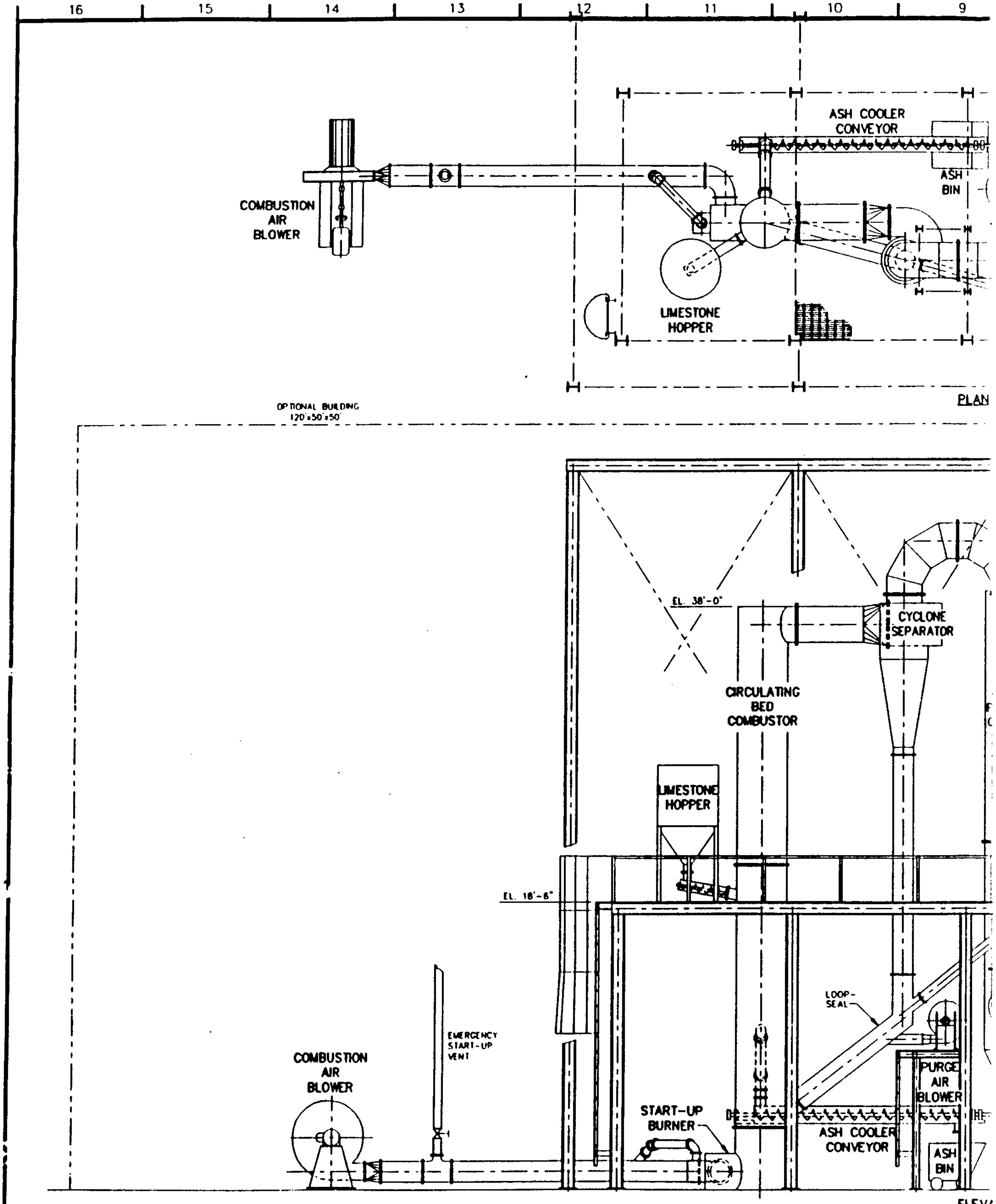
Location: Outdoors or in temperary bldg.

SPECIFICATIONS

1. Drum capacity to be 55 gallons.
2. Drum to include hinged inspection lid with entrance port for ash inlet.
3. Materials of construction to be carbon steel.

H5002A&B.WK1

10.0 GENERAL ARRANGEMENT DRAWINGS

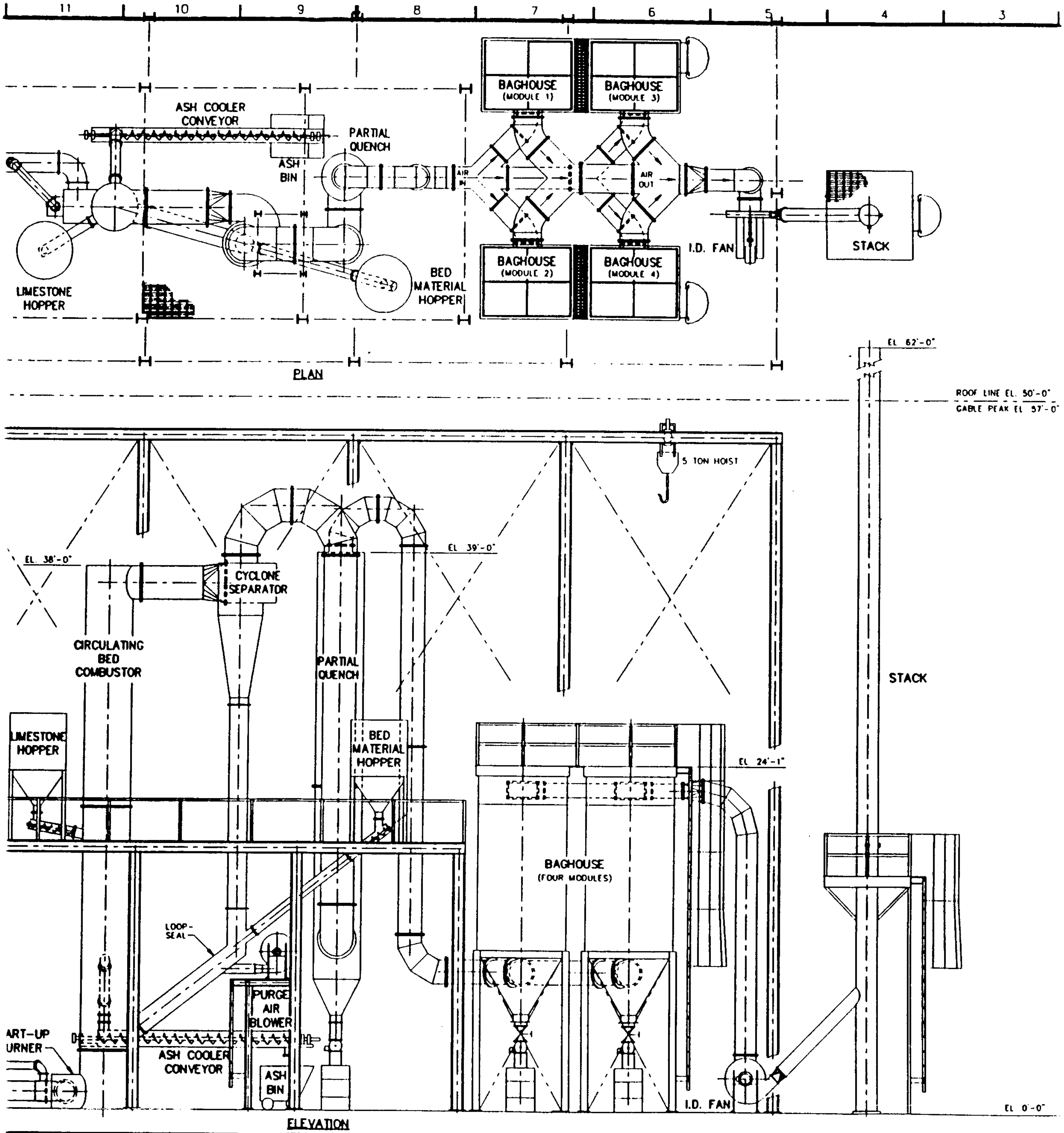


NOTES

1 5 TON HOIST WILL BE USED FOR FEEDING THE HOPPERS AND FOR PLANT MAINTENANCE

2 THE UNIT MAY BE INSTALLED IN A BUTLER TYPE BUILDING DUE TO THE TEMPORARY NATURE OF THE FACILITY.

1



(2)

A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	STC	MPB	PA	PA	PA	
NO	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR

STARTING DATE 9/28/94 | INITIATOR WS | CHKD SN | DRAWN STC | CHKD | PROJECT MGR P. ACHARYA

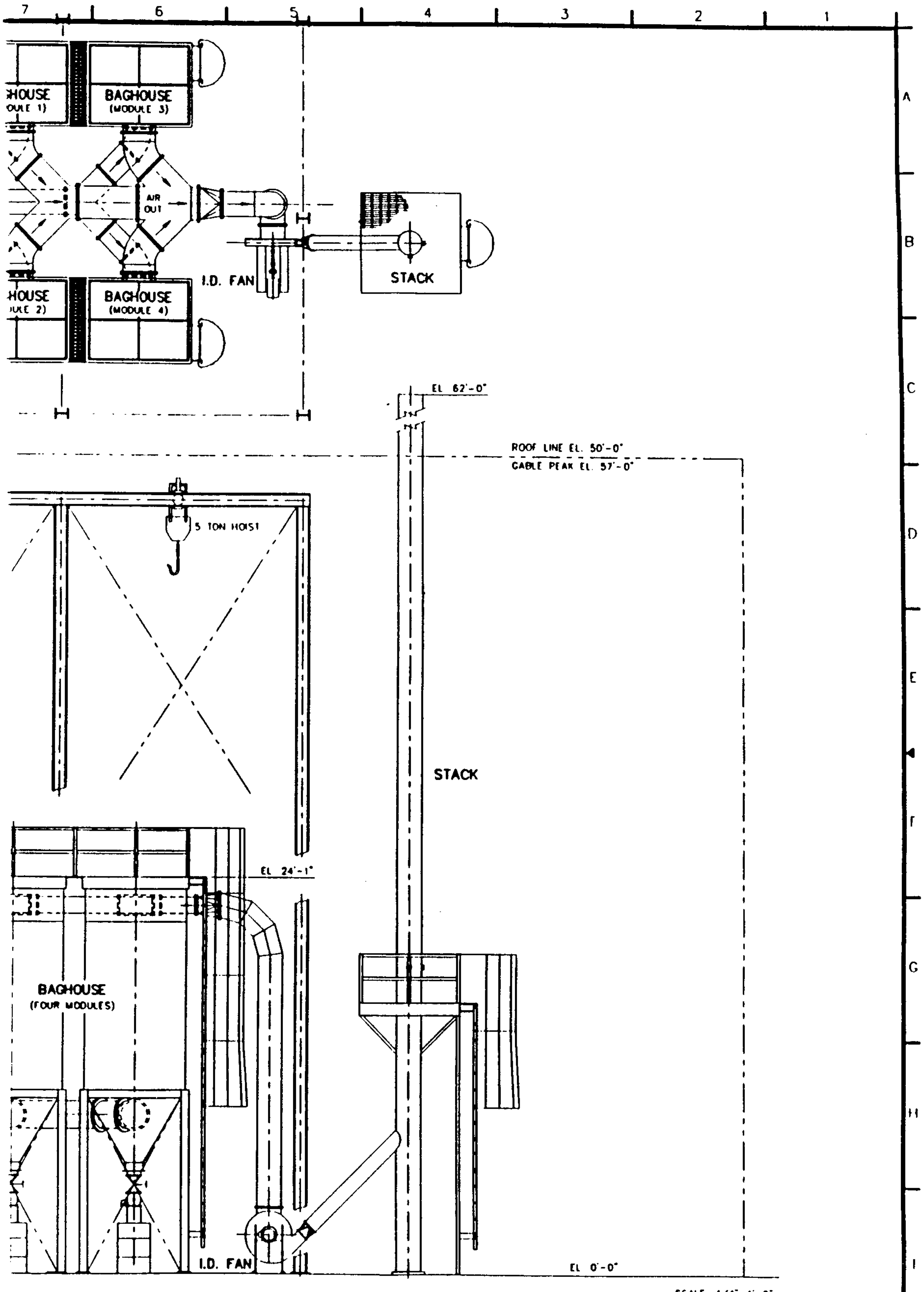
INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

U.S. AR
ABERDEEN

CIRCU
GE
P

PROJ. NO.
322243



INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

3

STC	MPB	PA	PA	PA	
BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR

PROJECT MGR P. ACHARYA

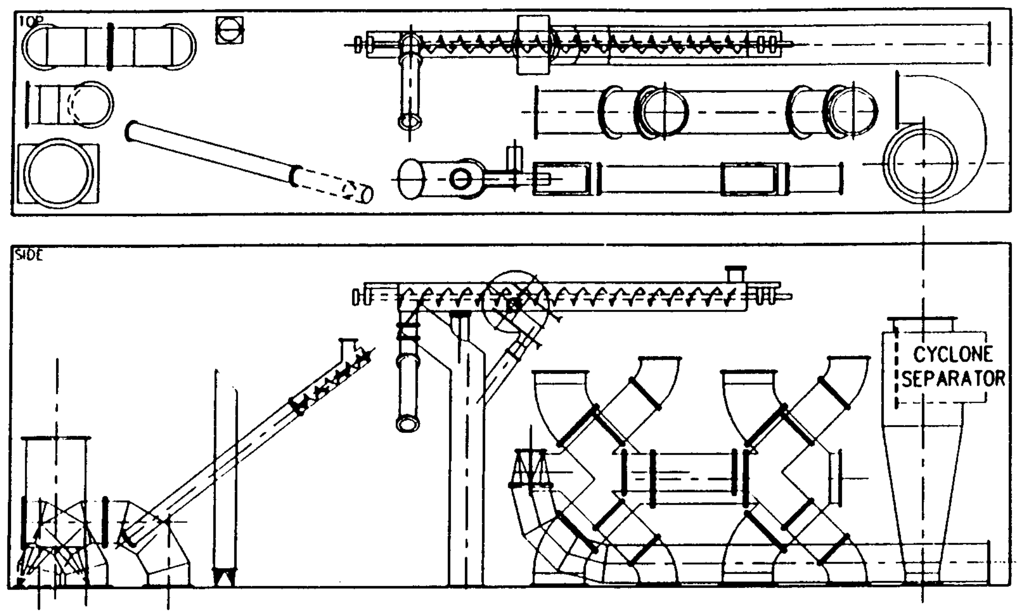
U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

CIRCULATING BED COMBUSTOR
GENERAL ARRANGEMENT
PLAN AND ELEVATION

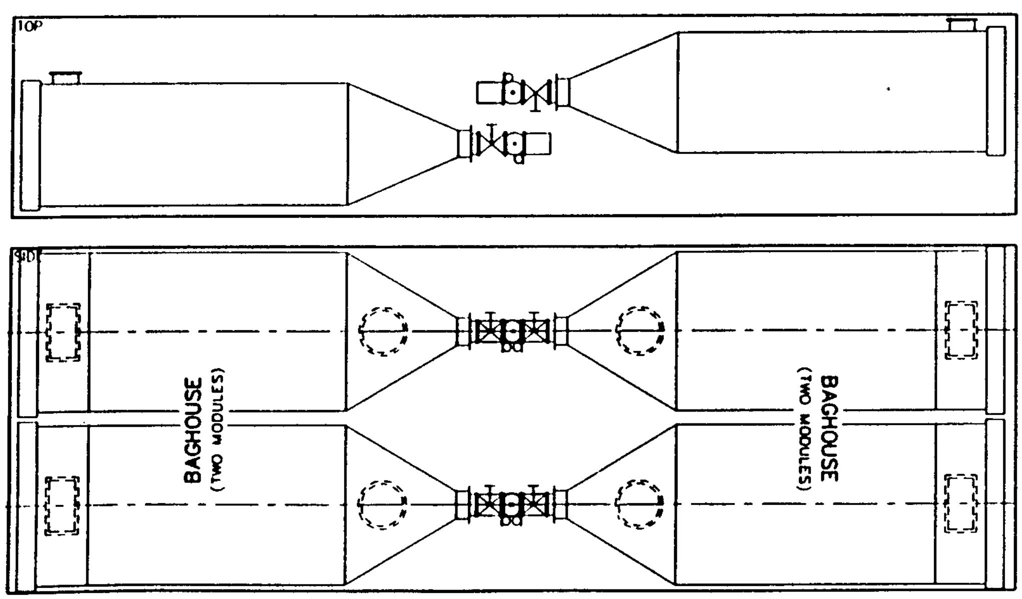
PROJ. NO.	DRAWING NO.	REV
322243	D-10-02-001	A

16 15 14 13 12 11 10 9

TRAILER #1



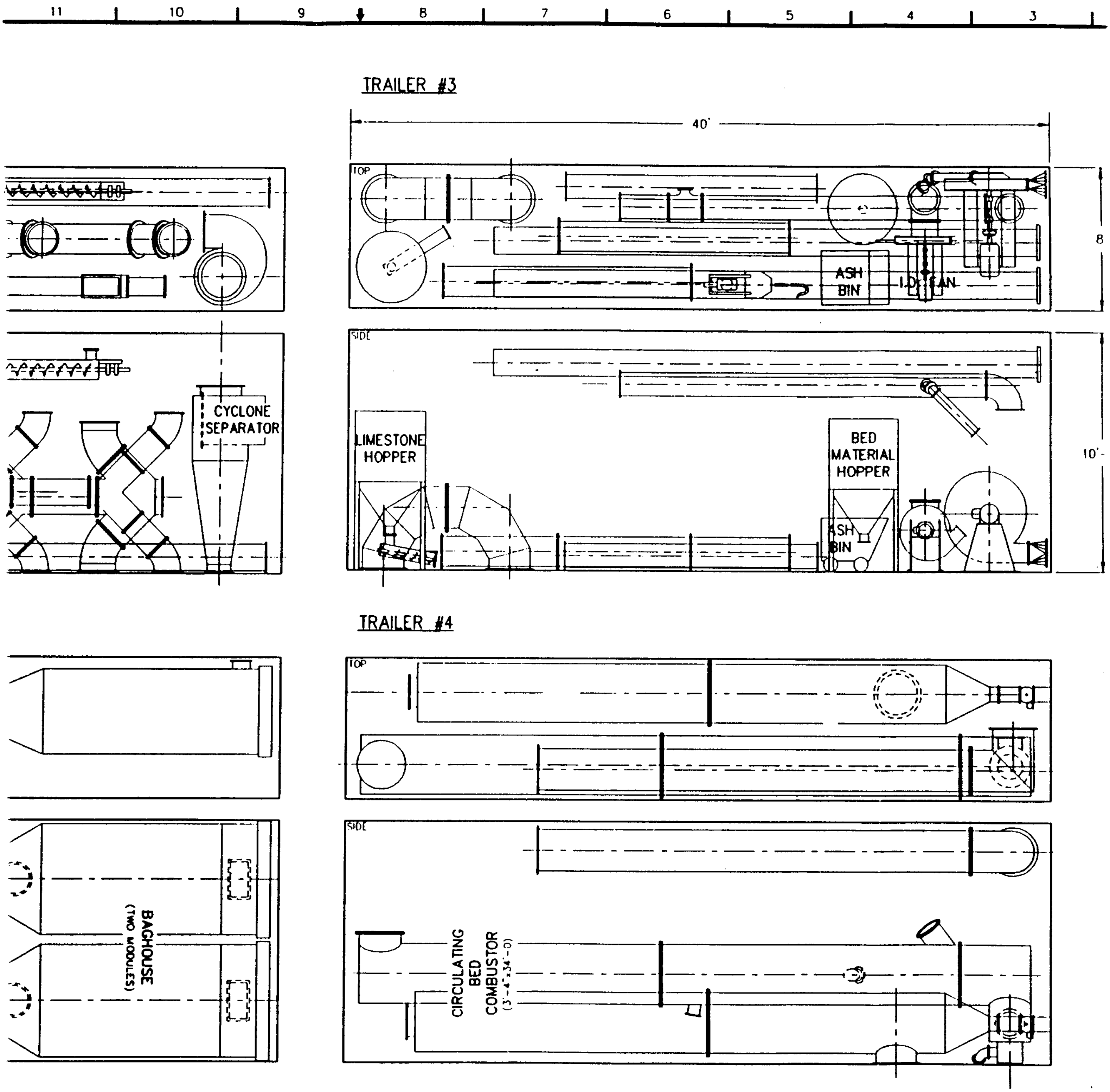
TRAILER #2



NOTES

1 PLAN AND ELEVATION SHOWN FOR EACH OF THE FOUR STANDARD SIZE TRAILERS
2 THIS LAYOUT IS FOR REFERENCE ONLY AND NOT TO BE USED FOR CONSTRUCTION PURPOSES
3 EQUIPMENT NOT SHOWN ON THE TRAILERS WILL BE TRANSPORTED IN A SEPARATE STANDARD SIZED TRAILER

1



NO	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR
A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	DJH	PA	PA	PA	PA	

STARTING DATE 9/26/94 INITIATOR PA / CHKD PA DRAWN DJH / CHKD PA PROJECT MGR P ACHARYA

2

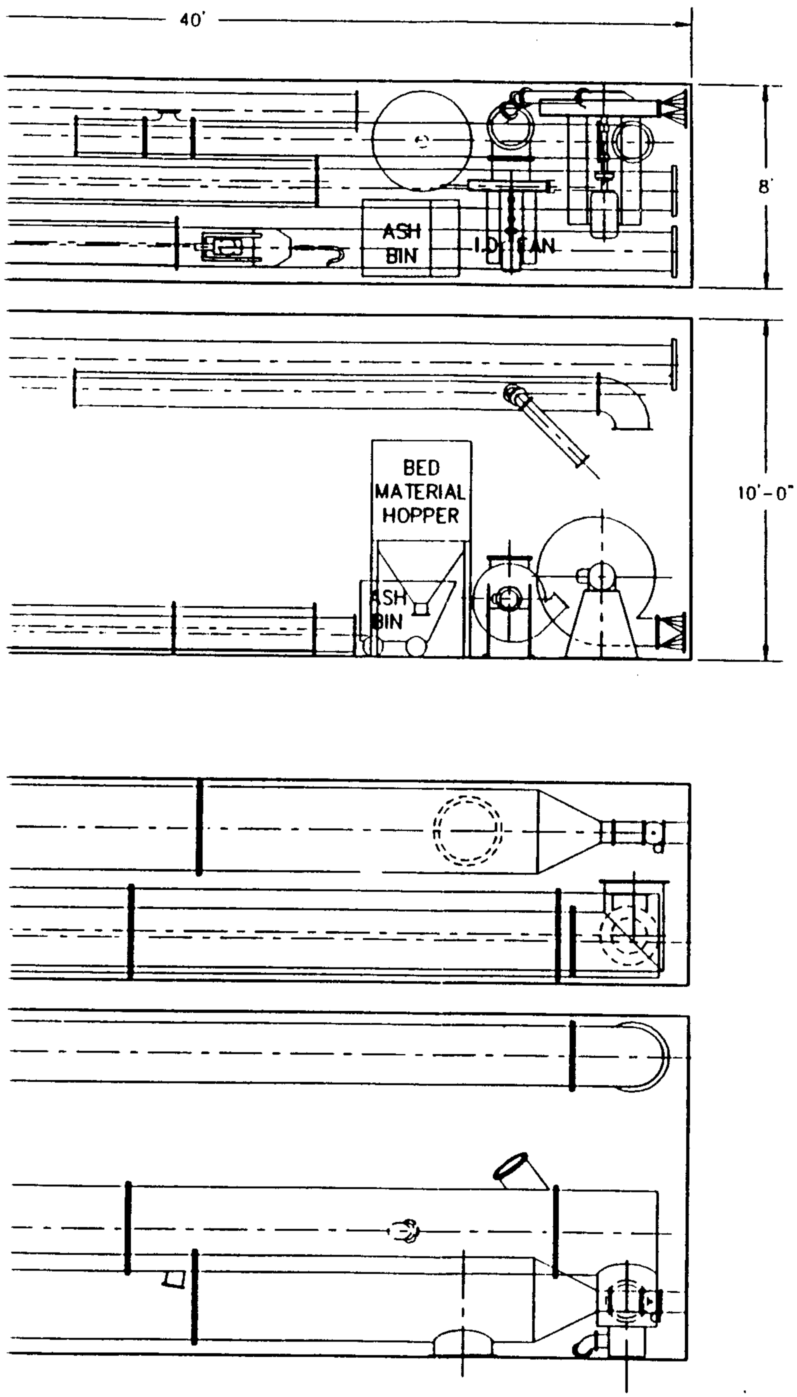
INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

U.S. ARMY
ABERDEEN F

SHIF

PROJ. NO.
322243



INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

A	PA	PA	
	ENGR	PROJ MGR	APPR

PROJECT P. ACHARYA

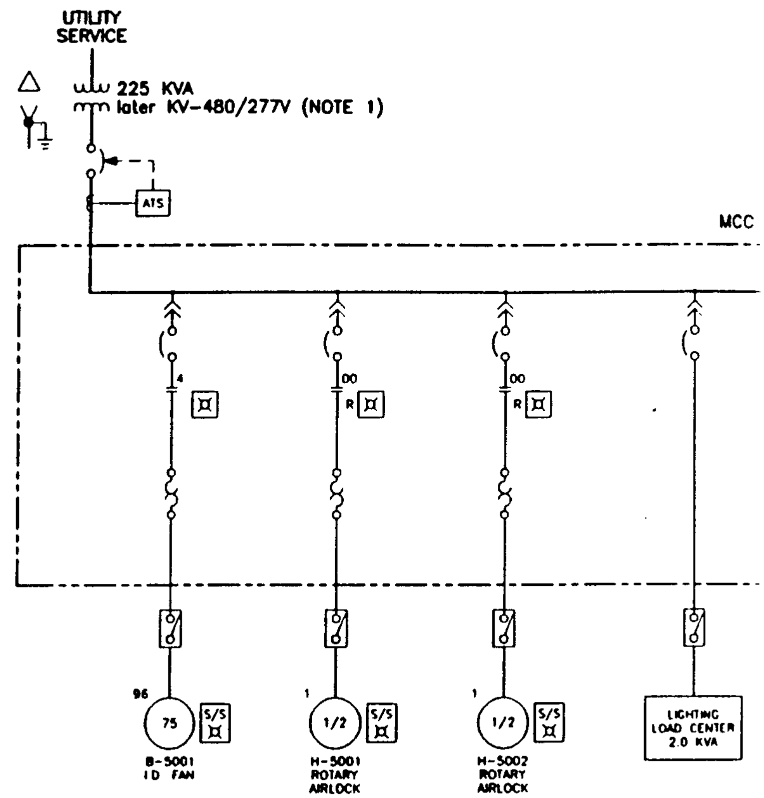
U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

3

SHIPPING ARRANGEMENT

PROJ. NO.	DRAWING NO.	REV
322243	D-10-02-002	A

11.0 ELECTRICAL ONE-LINE DRAWING



LEGEND:

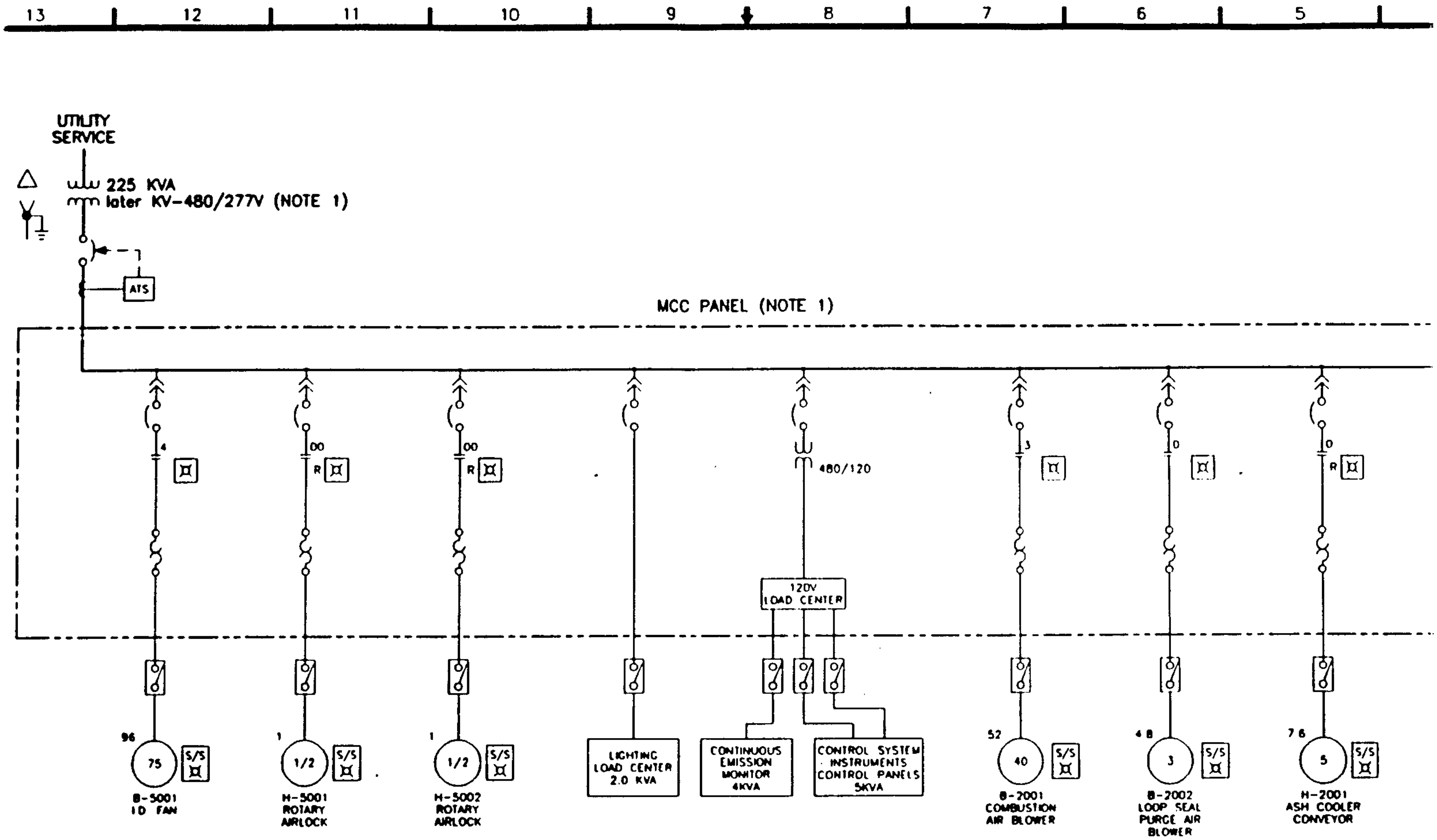
- DISCONNECT
- XFMR
- FLA (25) MOTOR LOAD W/HP REF. AND FULL LOAD AMPS (FLA)
- MOTOR OVERLOAD PROTECTION
- CKT BREAKER
- CONNECTOR PLUG
- FUSE
- 2 R MOTOR CONTROLLER W/SIZE REVERSING
- ATS AUTOMATIC LINE TRANSFER SWITCH
- RUN LIGHT
- S/S LOCAL START/STOP STATION WITH RUN LIGHT

32224307 11/17/94 3:02pm JRH

NOTES

1 CEM, MOTORS, LOCAL DISCONNECTS AND START/STOP STATIONS ARE FURNISHED BY THE CONTRACTOR
ALL OTHER EQUIPMENT AND WIRING THE FACILITY

1



NOTES

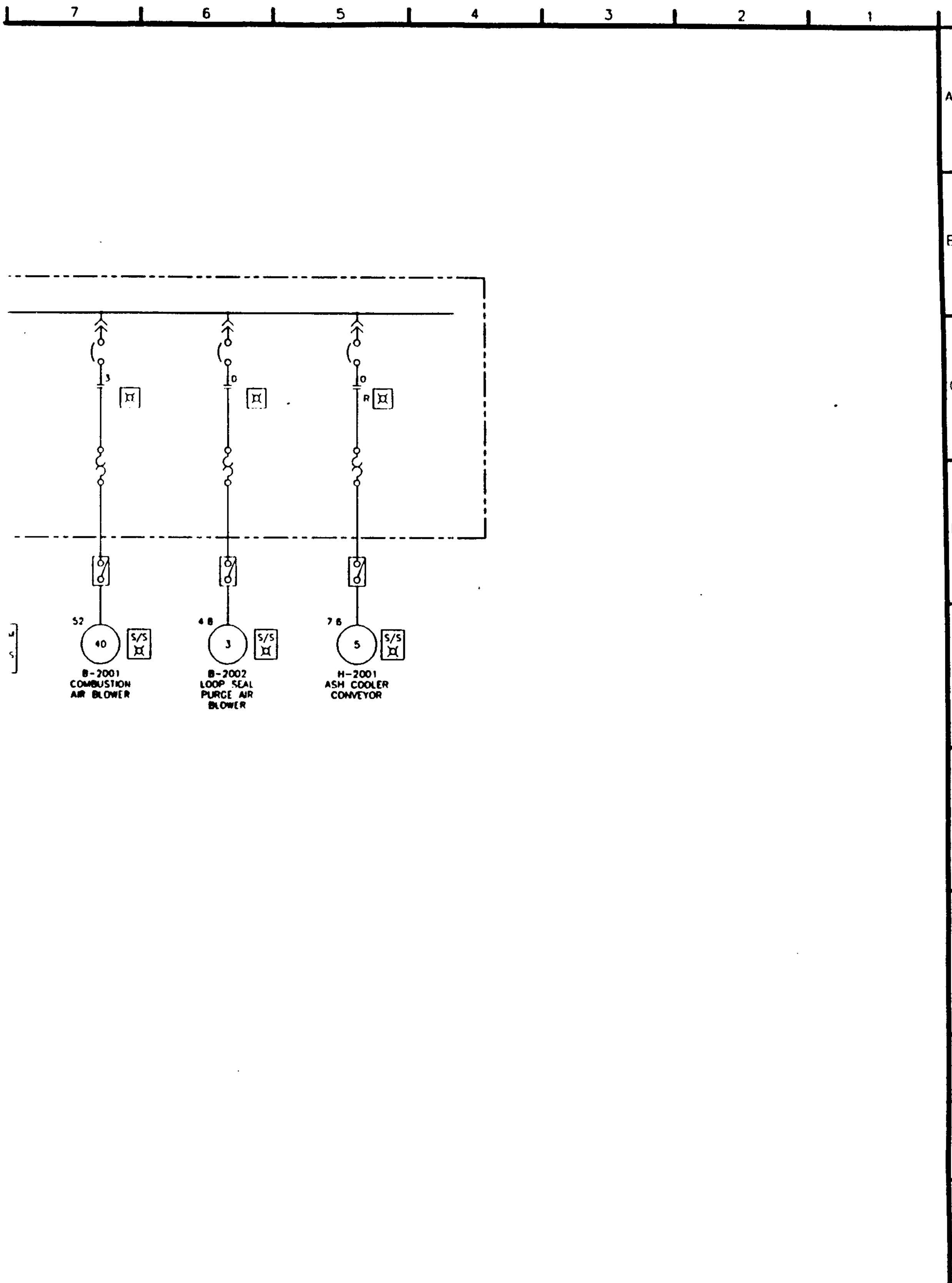
THE CONTRACTOR

(2)

NO.	DATE	REVISION	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR
A	10/13/94	FOR FINAL SUBMITTAL TO USAEC	JWH	MVD	MVD	MVD	PA	

STARTING DATE 9/12/94 INITIATOR MVD / CHKD MVD DRAWN JWH / CHKD MVD PROJECT MGR P ACHARYA

INTERNATIO[NAL] TECHNOLOG[Y] CORPORATI[ON]
Knoxville, Tennessee



SAEC	JWH	MVD	MVD	MVD	PA	
	BY	CHKD	DSGN ENGR	ENGR	PROJ MGR	APPR

DRAWN JWH / CHKD MVD PROJECT MGR P ACHARYA

INTERNATIONAL TECHNOLOGY CORPORATION

Knoxville, Tennessee

U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND

3

AREA 100
ELECTRICAL ONE-LINE
CIRCULATING BED COMBUSTOR SYSTEM

PROJ. NO.	DRAWING NO.	REV
322243	D-100-60-001	A

12.0 MASS AND ENERGY BALANCE OUTPUTS (Normal Case, Start-Up Case, and Hot Idle Case)

12.0 Mass and Energy Balance Outputs (Normal Case, Start-Up Case, and Hot Idle Case)

Mass and Energy Balance Process Strategy. An M&EB was performed on the red water feed (heating value = 487 Btu/lb) consisting of 15 percent solids and the balance water. A total of three M&EBs were performed for the conceptual design. They are:

- Normal case
- Start-up case
- Hot idle case.

During the normal case, 1.5 gpm of red water is processed in the incinerator with a cyclone exit gas temperature of 1600°F. The gases are then processed in the APCS. The data from this output are used to generate the table that formed the conceptual design basis and also used in the preparation of the PFD.

During the start-up case, there is no red water feed and a natural gas-fired start-up burner is used to preheat the combustion air. This burner in turn heats up and circulates the bed material. During this case, the cyclone exit gas temperature is maintained at approximately 1300°F, which is above the auto ignition temperature of natural gas. The data from this output are used to determine the turn down ratio of the system. These data are presented in Chapter 5.0.

During the hot idle case with no feed to the CBC, the cyclone exit gas is maintained at 600°F using the start-up burner. The hot gases at 600°F are adequate for keeping the CBC and the APCS warm when the system is idle.

UNIT NO	COMBUSTION DEVICE	BASE CONDITIONS			SPECIFIC HEAT (BTU/LB-F)	MOLECULAR WEIGHT (LB/LB-MOLE)
1	CIRC. BED/CYCLONE	ATM PRES (IN. H2O): 406.800	ASH		.270	100.000
		BASE TEMP (F): 60.000	MSALT		.270	100.000
		TOTAL NUMBER OF FUELS: 5	ASALT		.270	100.000
			FIXED CARBON		.220	12.011
			INERT		.270	100.000
			PYRO GAS		.500	100.000

COMBUSTION MODULE

OPERATING CONDITIONS	UNIT 1
EXIT GAS TEMPERATURE (F)	1600.000
EXIT SOLID TEMPERATURE (F)	1600.000
PRESSURE DROP (IN.W.C.)	2.000
OUT PRESSURE (IN. W.C.)	404.800
RADIATION HEAT LOSS	.630
HEAT LOSS UNIT	MM BTU/HR
HEAT INPUT (MM BTU/HR)	.000
EXCESS AIR (%) FOR OXIDIZED WASTE	28.664
MINIMUM XS AIR (%) FOR OXIDIZED WASTE	.000
MINIMUM O2 (%) IN EXIT GAS	5.000
AIR TEMPERATURE TO BURNER (F)	60.000
AIR HUMIDITY (LB H2O/LB DRY AIR)	.010
EXCESS AIR FOR AUX FUEL (%)	.000
NAME OF AUXILIARY FUEL	NAT GAS
QUENCH CODE (1 AIR,2 H2O)	1
QUENCH H2O TEMPERATURE TO BURNER (F)	.000
ASH IN EXIT (%)	6.000
MSALT IN EXIT (%)	100.000
ASALT IN EXIT (%)	100.000
FIXED CARBON IN EXIT (%)	.000
CO/CO2 COMBUSTION EFFICIENCY (%)	99.990
FUEL NO2 EFFICIENCY (%)	2.500

ASH MODULE CONDITIONS	
EXIT STEAM DESTINATION	ATMOSPHERE
HEAT LOSS (MM BTU/HR)	.000
SOLID EXIT TEMPERATURE (F)	.000
QUENCH WATER (GPM)	.000
MOISTURE IN WET ASH (%)	.000
QUENCH H2O MAKEUP TEMPERATURE (F)	60.000
QUENCH H2O TSS (mg/l)	.000
QUENCH H2O TDS (mg/l)	.000

FUEL TO: CIRC. BED/CYCLONE (PER HOUR)

FUEL NAME		C	H2	O2	N2	H2O	CL2	S	P
250	NAT GAS								
	PERCENT	73.928	24.431	.891	.750	.000	.000	.000	.000
	POUNDS	83.704	27.662	1.009	.849	.000	.000	.000	.000
	LB-MOLE	6.969	13.721	.032	.030	.000	.000	.000	.000
251	NAT GAS								
	PERCENT	73.928	24.431	.891	.750	.000	.000	.000	.000
	POUNDS	51.010	16.857	.615	.518	.000	.000	.000	.000
	LB-MOLE	4.247	8.362	.019	.018	.000	.000	.000	.000
252	REDSOLID								
	PERCENT	20.000	.670	21.000	6.330	.000	.000	4.330	.000
	POUNDS	24.780	.830	26.019	7.843	.000	.000	5.365	.000
	LB-MOLE	2.063	.412	.813	.280	.000	.000	.167	.000
253	REDWATER								
	PERCENT	.000	.000	.000	.000	100.000	.000	.000	.000
	POUNDS	.000	.000	.000	.000	702.100	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	38.971	.000	.000	.000
	TOT FUEL								
	POUNDS	159.494	45.349	27.643	9.210	702.100	.000	5.365	.000
	LB-MOLE	13.279	22.495	.864	.329	38.971	.000	.167	.000

FUEL TO: CIRC. BED/CYCLONE (PER HOUR) (CONTINUED)

FUEL NAME		************ COMPONENT FLOW TO FURNACE ************							
		SI	BR2	F2	ASH	MSALT	ASALT	F.CARB	INERTS
250	NAT GAS								
	PERCENT	.000	.000	.000	.000	.000	.000	.000	.000
	POUNDS	.000	.000	.000	.000	.000	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	.000	.000	.000	.000
251	NAT GAS								
	PERCENT	.000	.000	.000	.000	.000	.000	.000	.000
	POUNDS	.000	.000	.000	.000	.000	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	.000	.000	.000	.000
252	REDSOLID								
	PERCENT	.000	.000	.000	.000	2.670	45.000	.000	.000
	POUNDS	.000	.000	.000	.000	3.308	55.755	.000	.000
	LB-MOLE	.000	.000	.000	.000	.033	.558	.000	.000
253	REDWATER								
	PERCENT	.000	.000	.000	.000	.000	.000	.000	.000
	POUNDS	.000	.000	.000	.000	.000	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	.000	.000	.000	.000
		--------	---------	----------	----------	----------	----------	----------	------------
	TOT FUEL								
	POUNDS	.000	.000	.000	.000	3.308	55.755	.000	.000
	LB-MOLE	.000	.000	.000	.000	.033	.558	.000	.000

UNIT 1 CIRC. BED/CYCLONE

*** MASS AND ENERGY IN ***

	FUELS:	USE CODE	TEMP DEG F	LB/HR	BTU/LB	MM BTU/HR	% OF TOTAL HEAT DUTY
250	NAT GAS	OXD	60.00	113.224	21800.000	2.468	55.921419
251	NAT GAS	OXD	60.00	69.000	21800.000	1.504	34.079197
252	REDSOLID	OXD	60.00	123.900	3200.000	.396	8.982662
253	REDWATER	OXD	60.00	702.100	.000	.000	.000000
351	COMBUSTION AIR						
	O2		60.00	981.785	.000	.000	.000000
	N2		60.00	3252.238	.000	.000	.000000
	H2O		60.00	42.340	1059.900	.045	1.016721
				==========		=======	==========
	OVERALL TOTAL			5284.588		4.414	100.000000

*** MASS AND ENERGY OUT ***

350 COMBUSTION GAS OUT 1600.00 DEG F , 404.8 IN. W.C.

		LB-MOLES/HR	LB/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
	H2O	63.816	1149.704	1833.457	2.108	.282	LB H2O/LB DRY GAS
	CO2	13.278	584.365	407.805	.238	9.713	% GAS VOL (DRY)
	CO	.001	.037	411.485	.000	9.714	PPMV (DRY)
	N2	116.406	3261.218	406.902	1.327	85.152	% GAS VOL (DRY)
	NO2	.016	.756	376.359	.000	120.233	PPMV (DRY)
	O2	6.835	218.726	377.212	.083	5.000	% GAS VOL (DRY)
	SO2	.167	10.719	286.955	.003	1223.945	PPMV (DRY)
	MSALT	.033	3.308	415.800	.001	.385	GR/DSCF @ 7% O2
	ASALT	.558	55.755	415.800	.023	6.483	GR/DSCF @ 7% O2
		----------	----------	---------	-------		
	TOTAL COMBUSTION GAS	201.110	5284.588	715.983	3.784		
353	HEAT LOSS				.630		

	TOTAL HEAT RELEASED				4.414		
354	CO Hc AVAILABLE			4343.600	.000		
		==========	==========		=======		
	OVERALL TOTAL	201.110	5284.588		4.414		
	TOTAL DRY GAS	136.704	4075.821		1.651		

COMBUSTION AIR SUMMARY OPERATING CONDITIONS	UNIT 1
TEMPERATURE (F)	60.000
PRESSURE (IN. W.C.)	406.800
FLOW (ACFM)	928.285
AIR (DRY) TOTAL (LB/HR)	4234.024
AIR (DRY) THEORETICAL (LB/HR)	3290.753
AIR (DRY) TOT-THEO (LB/HR)	943.271
EXCESS AIR (%)	28.664
TOTAL O2 (LB/HR)	981.785
THEO. O2 (LB/HR)	763.060
TOT-THEO. O2 (LB/HR)	218.726
TOTAL N2 (LB/HR)	3252.238
THEO. N2 (LB/HR)	2527.693
TOT-THEO. N2 (LB/HR)	724.545

COMBUSTION GAS SUMMARY	UNIT 1
TEMPERATURE (F)	1600.000
PRESSURE (IN. W.C.)	404.800
FLOW (ACFM)	5051.309

BASE CONDITIONS AND INCOMING GAS CONDITIONS	
ATMOSPHERIC PRESSURE (IN. H2O)	406.80
BASE TEMPERATURE (DEG F)	60.00
INLET GAS PRESSURE (IN. H2O)	404.80
INLET GAS TEMPERATURE (DEG F)	1600.00

PARTICULATE STANDARD INFORMATION	
PARTICULATE STANDARD BASIS	O2
PARTICULATE STANDARD BASIS CONCENTRATION (%)	7.00
PARTICULATE STANDARD BASIS CONDITION	DSCF
PARTICULATE STANDARD TEMPERATURE (DEG F)	68.00

UNIT NO	APC DEVICE	RECEIVER
1	PART. QUENCH	QUENCH SUMP
2	BAGHOUSE	DUSTCOLLECT
3	ID FAN	
4	STACK	

APC DEVICE INFORMATION	UNIT 1	UNIT 2	UNIT 3	UNIT 4
RECYCLE FLOW (GPM)	.00	.00	.00	.00
RECYCLE FLOW (LB/HR)	.00	.00	.00	.00
OUTLET PRESSURE (IN. H2O)	403.80	383.80	407.80	406.80
APC HEAT LOSS (MM BTU/HR)	.00	.00	.00	.00

PERCENT REMOVAL DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
ASH	.00	99.00	.00	.00
METAL SALTS	.00	99.00	.00	.00
ALKALI SALTS	.00	99.00	.00	.00

RECEIVER DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
REC. EXISTENCE	NO	YES	NO	NO
REC. PURGE DESTINATION	0	0	0	0
REC. PURGE TARGET	DIS	DIS	DIS	DIS
REC. SS REMOVAL EFFICIENCY	.00	.00	.00	.00
REC. HEAT LOSS (MM BTU/HR)	.00	.00	.00	.00

MAKEUP STREAM DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
MAKEUP OPTION	APC	APC	REC	REC
MAKEUP FLOW (GPM)	3.10	.00	.00	.00
MAKEUP TDS (MG/L)	200.00	.00	.00	.00
MAKEUP TSS (MG/L)	.00	.00	.00	.00
MAKEUP TEMP. (DEG F)	60.00	60.00	60.00	60.00

NEUTRALIZATION STREAM DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
NEUT. OPTION	APC	APC	REC	REC
NEUT. REAGENT NAME	NAOH	NAOH	NAOH	NAOH
NEUT. REAG. TEMP. (DEG F)	60.00	60.00	60.00	60.00
NEUT. REAG. CONC. (%)	23.00	23.00	20.00	20.00
STOICHIOMETRIC RATIO	1.00	1.00	1.00	1.00

OPERATIONAL LIMITS DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
MIN. GAS OUT. TEMP. (DEG F)	0.	0.	0.	0.
PURGE TDS CONCENTRATION (%)	0.	0.	0.	0.
PURGE TSS CONCENTRATION (%)	0.	0.	0.	0.
PURGE ACID CONCENTRATION (%)	0.	0.	0.	0.

OTHER GAS DATA	GAS 1
NAME OF OTHER GAS	ATM AIR
FEED RATE (LB/HR)	775.00
TEMPERATURE (DEG F)	60.00
INPUT CODE	2.
DESTINATION UNIT NUMBER	1.

OTHER GAS COMP. DATA (LB/HR)	GAS 1
H2O	7.75
N2	589.39
O2	177.86

UNIT 1 PART. QUENCH

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
350 GAS FROM CIRC. BED/CYCLONE: 1600.0 DEG F, 404.8 IN. W.C.						
H2O	63.816	1149.704	1833.457	2.108	.282	LB H2O/LB DRY GAS
CO2	13.278	584.365	407.805	.238	9.713	% DRY GAS VOL
CO	.001	.037	411.485	.000	9.714	PPM DRY GAS VOL
N2	116.406	3261.218	406.902	1.327	85.152	% DRY GAS VOL
NO2	.016	.756	376.359	.000	120.233	PPM DRY GAS VOL
O2	6.835	218.726	377.212	.083	5.000	% DRY GAS VOL
SO2	.167	10.719	286.955	.003	1223.945	PPM DRY GAS VOL
METAL SALTS	.033	3.308	415.800	.001	.385	GR DSCF @ 7.0 % O2
ALKALI SALTS	.558	55.755	415.800	.023	6.483	GR DSCF @ 7.0 % O2
TOTAL FLUE GAS	201.110	5284.588		3.784	6.868	GR DSCF @ 7.0 % O2
738 ATM AIR: 60.0 DEG F						
H2O	.430	7.750	1059.900	.008	.010	LB H2O/LB DRY GAS
N2	21.038	589.387	.000	.000	79.101	% DRY GAS VOL
O2	5.558	177.863	.000	.000	20.899	% DRY GAS VOL
TOTAL GAS	27.026	775.000		.008	.000	GR DSCF @ 7.0 % O2
651 MAKEUP WATER: 60.0 DEG F						
H2O	85.982	1549.051	.000	.000		
TDS	.003	.310	36.000	.000		
TOTAL MAKEUP	85.985	1549.361		.000		
OVERALL TOTAL	314.121	7608.949		3.792		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
650 GAS TO BAGHOUSE: 439.2 DEG F, 403.8 IN. W.C.						
H2O	150.228	2706.505	1233.052	3.337	.559	LB H2O/LB DRY GAS
CO2	13.278	584.365	84.275	.049	8.131	% DRY GAS VOL
CO	.001	.037	95.078	.000	8.132	PPM DRY GAS VOL
N2	137.443	3850.605	94.716	.365	84.166	% DRY GAS VOL
NO2	.016	.756	78.743	.000	100.651	PPM DRY GAS VOL
O2	12.393	396.588	85.425	.034	7.589	% DRY GAS VOL
SO2	.167	10.719	61.120	.001	1024.607	PPM DRY GAS VOL
METAL SALTS	.033	3.308	102.384	.000	.384	GR DSCF @ 7.0 % O2
ALKALI SALTS	.558	55.755	102.384	.006	6.475	GR DSCF @ 7.0 % O2
TOTAL FLUE GAS	314.118	7608.639		3.792	6.859	GR DSCF @ 7.0 % O2
655 PURGE FROM PART. QUENCH: 439.2 DEG F						
ALKALI SALTS	.003	.310	102.384	.000	100.00000	WT %
TOTAL PURGE	.003	.310		.000	.00000	WT % TSS
OVERALL TOTAL	314.121	7608.949		3.792		
DRY GAS TOTAL	163.890	4902.134		.455		

UNIT 2 BAGHOUSE

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
650 GAS FROM PART. QUENCH: 439.2 DEG F, 403.8 IN. W.C.						
H2O	150.228	2706.505	1233.052	3.337	.559	LB H2O/LB DRY GAS
CO2	13.278	584.365	84.275	.049	8.131	% DRY GAS VOL
CO	.001	.037	95.078	.000	8.132	PPM DRY GAS VOL
N2	137.443	3850.605	94.716	.365	84.166	% DRY GAS VOL
NO2	.016	.756	78.743	.000	100.651	PPM DRY GAS VOL
O2	12.393	396.588	85.425	.034	7.589	% DRY GAS VOL
SO2	.167	10.719	61.120	.001	1024.607	PPM DRY GAS VOL
METAL SALTS	.033	3.308	102.384	.000	.384	GR DSCF @ 7.0 % O2
ALKALI SALTS	.558	55.755	102.384	.006	6.475	GR DSCF @ 7.0 % O2
TOTAL FLUE GAS	314.118	7608.639		3.792	6.859	GR DSCF @ 7.0 % O2
OVERALL TOTAL	314.118	7608.639		3.792		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
661 GAS TO ID FAN: 439.2 DEG F, 383.8 IN. W.C.						
H2O	150.228	2706.505	1233.052	3.337	.559	LB H2O/LB DRY GAS
CO2	13.278	584.365	84.275	.049	8.131	% DRY GAS VOL
CO	.001	.037	95.078	.000	8.132	PPM DRY GAS VOL
N2	137.443	3850.605	94.716	.365	84.166	% DRY GAS VOL
NO2	.016	.756	78.743	.000	100.651	PPM DRY GAS VOL
O2	12.393	396.588	85.425	.034	7.589	% DRY GAS VOL
SO2	.167	10.719	61.120	.001	1024.607	PPM DRY GAS VOL
METAL SALTS	.000	.033	102.384	.000	.004	GR DSCF @ 7.0 % O2
ALKALI SALTS	.006	.558	102.384	.000	.065	GR DSCF @ 7.0 % O2
TOTAL FLUE GAS	313.533	7550.166		3.786	.069	GR DSCF @ 7.0 % O2
OVERALL TOTAL	313.533	7550.166		3.786		
DRY GAS TOTAL	163.305	4843.661		.449		

UNIT 2 DUSTCOLLECT

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION
OVERALL TOTAL	.000	.000		.000	

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION
666 PURGE FROM DUSTCOLLECT: 439.2 DEG F					
METAL SALTS	.033	3.275	102.384	.000	5.60101 WT % SS
ALKALI SALTS	.552	55.197	102.384	.006	94.39899 WT %
TOTAL PURGE	.585	58.472		.006	5.60101 WT % TSS
OVERALL TOTAL	.585	58.472		.006	

UNIT 3 ID FAN

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
661 GAS FROM BAGHOUSE: 439.2 DEG F, 383.8 IN. W.C.						
H2O	150.228	2706.505	1233.052	3.337	.559	LB H2O/LB DRY GAS
CO2	13.278	584.365	84.275	.049	8.131	% DRY GAS VOL
CO	.001	.037	95.078	.000	8.132	PPM DRY GAS VOL
N2	137.443	3850.605	94.716	.365	84.166	% DRY GAS VOL
NO2	.016	.756	78.743	.000	100.651	PPM DRY GAS VOL
O2	12.393	396.588	85.425	.034	7.589	% DRY GAS VOL
SO2	.167	10.719	61.120	.001	1024.607	PPM DRY GAS VOL
METAL SALTS	.000	.033	102.384	.000	.004	GR DSCF @ 7.0 % O2
ALKALI SALTS	.006	.558	102.384	.000	.065	GR DSCF @ 7.0 % O2
TOTAL FLUE GAS	313.533	7550.166		3.786	.069	GR DSCF @ 7.0 % O2
682 HEAT OF COMPRESSION				.043		
OVERALL TOTAL	313.533	7550.166		3.829		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
672 GAS TO STACK: 456.4 DEG F, 407.8 IN. W.C.						
H2O	150.228	2706.505	1241.152	3.359	.559	LB H2O/LB DRY GAS
CO2	13.278	584.365	88.465	.052	8.131	% DRY GAS VOL
CO	.001	.037	99.467	.000	8.132	PPM DRY GAS VOL
N2	137.443	3850.605	99.071	.381	84.166	% DRY GAS VOL
NO2	.016	.756	82.624	.000	100.651	PPM DRY GAS VOL
O2	12.393	396.588	89.437	.035	7.589	% DRY GAS VOL
SO2	.167	10.719	64.123	.001	1024.607	PPM DRY GAS VOL
METAL SALTS	.000	.033	107.040	.000	.004	GR DSCF @ 7.0 % O2
ALKALI SALTS	.006	.558	107.040	.000	.065	GR DSCF @ 7.0 % O2
TOTAL FLUE GAS	313.533	7550.166		3.829	.069	GR DSCF @ 7.0 % O2
OVERALL TOTAL	313.533	7550.166		3.829		
DRY GAS TOTAL	163.305	4843.661		.469		

UNIT 4 STACK

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
672 GAS FROM ID FAN: 456.4 DEG F, 407.8 IN. W.C.						
H2O	150.228	2706.505	1241.152	3.359	.559	LB H2O/LB DRY GAS
CO2	13.278	584.365	88.465	.052	8.131	% DRY GAS VOL
CO	.001	.037	99.467	.000	8.132	PPM DRY GAS VOL
N2	137.443	3850.605	99.071	.381	84.166	% DRY GAS VOL
NO2	.016	.756	82.624	.000	100.651	PPM DRY GAS VOL
O2	12.393	396.588	89.437	.035	7.589	% DRY GAS VOL
SO2	.167	10.719	64.123	.001	1024.607	PPM DRY GAS VOL
METAL SALTS	.000	.033	107.040	.000	.004	GR DSCF @ 7.0 % O2
ALKALI SALTS	.006	.558	107.040	.000	.065	GR DSCF @ 7.0 % O2
TOTAL FLUE GAS	313.533	7550.166		3.829	.069	GR DSCF @ 7.0 % O2
OVERALL TOTAL	313.533	7550.166		3.829		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
683 GAS TO ATMOSPHERE: 456.4 DEG F, 406.8 IN. W.C.						
H2O	150.228	2706.505	1241.152	3.359	.559	LB H2O/LB DRY GAS
CO2	13.278	584.365	88.465	.052	8.131	% DRY GAS VOL
CO	.001	.037	99.467	.000	8.132	PPM DRY GAS VOL
N2	137.443	3850.605	99.071	.381	84.166	% DRY GAS VOL
NO2	.016	.756	82.624	.000	100.651	PPM DRY GAS VOL
O2	12.393	396.588	89.437	.035	7.589	% DRY GAS VOL
SO2	.167	10.719	64.123	.001	1024.607	PPM DRY GAS VOL
METAL SALTS	.000	.033	107.040	.000	.004	GR DSCF @ 7.0 % O2
ALKALI SALTS	.006	.558	107.040	.000	.065	GR DSCF @ 7.0 % O2
TOTAL FLUE GAS	313.533	7550.166		3.829	.069	GR DSCF @ 7.0 % O2
OVERALL TOTAL	313.533	7550.166		3.829		
DRY GAS TOTAL	163.305	4843.661		.469		

GAS FLOW SUMMARY AT APC DEVICE OUTLET

UNIT NO	STREAM	TEMPERATURE (DEG F)	PRESSURE (IN. W.C.)	FLOW (ACFM)	DRY GAS (SCFM)
1	PART. QUENCH	439.2	403.8	3455.493	1048.758
2	BAGHOUSE	439.2	383.8	3635.560	1048.758
3	ID FAN	456.4	407.8	3487.233	1048.758
4	STACK	456.4	406.8	3495.805	1048.758

LIQUID FLOW SUMMARY

MAKEUP STREAMS TO:	FLOW (GAL/MIN)	H2O (LB/HR)	TEMP (DEG F)	D.S. (LB/HR)	S.S. (LB/HR)
PART. QUENCH	3.100	1549.051	60.000	.310	.000
TOTAL	3.100	1549.051		.310	.000

DISCHARGE PURGE: ORIGINATION SUMP	TEMP (DEG F)	H2O (LB/HR)	ORGANIC (LB/HR)	D.S. (LB/HR)	S.S. (LB/HR)	ACIDS (LB/HR)
PART. QUENCH	439.201	.000	.000	.310	.000	.000
BAGHOUSE	439.201	.000	.000	55.197	3.275	.000
TOTAL PURGE	.000	.000	.000	55.507	3.275	.000

JOB NO: 322243 JOB DESC: CIRCULATING BED COMBUSTOR, 1300 F, START-UP CASE 9/ 9/94 11:30 PAGE 1
CLIENT: USAC ENGINEER: SLM DATA FILE: 1300.DAT
HEAT AND MATERIAL BALANCE PROGRAM VERSION 6.0

UNIT NO	COMBUSTION DEVICE	BASE CONDITIONS			SPECIFIC HEAT (BTU/LB-F)	MOLECULAR WEIGHT (LB/LB-MOLE)
1	CIRC. BED/CYCLONE	ATM PRES (IN. H2O):	406.800	ASH	.270	100.000
		BASE TEMP (F):	60.000	MSALT	.270	100.000
		TOTAL NUMBER OF FUELS:	5	ASALT	.270	100.000
				FIXED CARBON	.220	12.011
				INERT	.270	100.000
				PYRO GAS	.500	100.000

COMBUSTION MODULE

OPERATING CONDITIONS	UNIT 1
EXIT GAS TEMPERATURE (F)	1300.000
EXIT SOLID TEMPERATURE (F)	1300.000
PRESSURE DROP (IN.W.C.)	.050
OUT PRESSURE (IN. W.C.)	406.750
RADIATION HEAT LOSS	.630
HEAT LOSS UNIT	MM BTU/HR
HEAT INPUT (MM BTU/HR)	.000
EXCESS AIR (%) FOR OXIDIZED WASTE	52.307
MINIMUM XS AIR (%) FOR OXIDIZED WASTE	.000
MINIMUM O2 (%) IN EXIT GAS	7.700
AIR TEMPERATURE TO BURNER (F)	60.000
AIR HUMIDITY (LB H2O/LB DRY AIR)	.010
EXCESS AIR FOR AUX FUEL (%)	.000
NAME OF AUXILIARY FUEL	NAT GAS
QUENCH CODE (1 AIR,2 H2O)	1
QUENCH H2O TEMPERATURE TO BURNER (F)	.000
ASH IN EXIT (%)	6.000
MSALT IN EXIT (%)	100.000
ASALT IN EXIT (%)	100.000
FIXED CARBON IN EXIT (%)	.000
CO/CO2 COMBUSTION EFFICIENCY (%)	99.990
FUEL NO2 EFFICIENCY (%)	2.500

ASH MODULE CONDITIONS	
EXIT STEAM DESTINATION	ATMOSPHERE
HEAT LOSS (MM BTU/HR)	.000
SOLID EXIT TEMPERATURE (F)	.000
QUENCH WATER (GPM)	.000
MOISTURE IN WET ASH (%)	.000
QUENCH H2O MAKEUP TEMPERATURE (F)	60.000
QUENCH H2O TSS (mg/l)	.000
QUENCH H2O TDS (mg/l)	.000

FUEL TO: CIRC. BED/CYCLONE (PER HOUR)

FUEL NAME		C	H2	O2	N2	H2O	CL2	S	P
		*************	*************	*************	COMPONENT FLOW TO FURNACE	*************	*************	*************	*************
250	NAT GAS								
	PERCENT	73.928	24.431	.891	.750	.000	.000	.000	.000
	POUNDS	30.956	10.230	.373	.314	.000	.000	.000	.000
	LB-MOLE	2.577	5.074	.012	.011	.000	.000	.000	.000
251	NAT GAS								
	PERCENT	73.928	24.431	.891	.750	.000	.000	.000	.000
	POUNDS	14.786	4.886	.178	.150	.000	.000	.000	.000
	LB-MOLE	1.231	2.424	.006	.005	.000	.000	.000	.000
		--------	---------	----------	----------	----------	----------	----------	------------
	TOT FUEL								
	POUNDS	45.741	15.116	.551	.464	.000	.000	.000	.000
	LB-MOLE	3.808	7.498	.017	.017	.000	.000	.000	.000

FUEL TO: CIRC. BED/CYCLONE (PER HOUR) (CONTINUED)

FUEL NAME		****** COMPONENT FLOW TO FURNACE ******							
		SI	BR2	F2	ASH	MSALT	ASALT	F.CARB	INERTS
250	NAT GAS								
	PERCENT	.000	.000	.000	.000	.000	.000	.000	.000
	POUNDS	.000	.000	.000	.000	.000	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	.000	.000	.000	.000
251	NAT GAS								
	PERCENT	.000	.000	.000	.000	.000	.000	.000	.000
	POUNDS	.000	.000	.000	.000	.000	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	.000	.000	.000	.000
		--------	---------	----------	----------	----------	----------	----------	------------
	TOT FUEL								
	POUNDS	.000	.000	.000	.000	.000	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	.000	.000	.000	.000

UNIT 1 CIRC. BED/CYCLONE

	*** MASS AND ENERGY IN ***						% OF TOTAL
	FUELS:	USE CODE	TEMP DEG F	LB/HR	BTU/LB	MM BTU/HR	HEAT DUTY
250	NAT GAS	OXD	60.00	41.873	21800.000	.913	66.843081
251	NAT GAS	OXD	60.00	20.000	21800.000	.436	31.926784
351	COMBUSTION AIR						
	O2		60.00	367.521	.000	.000	.000000
	N2		60.00	1217.442	.000	.000	.000000
	H2O		60.00	15.850	1059.900	.017	1.230135
				==========		=======	==========
	OVERALL TOTAL			1662.686		1.366	100.000000

*** MASS AND ENERGY OUT ***

350 COMBUSTION GAS OUT 1300.00 DEG F , 406.8 IN. W.C.

		LB-MOLES/HR	LB/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
	H2O	8.378	150.935	1666.941	.252	.100	LB H2O/LB DRY GAS
	CO2	3.808	167.590	318.044	.053	7.434	% GAS VOL (DRY)
	CO	.000	.011	326.009	.000	7.434	PPMV (DRY)
	N2	43.471	1217.895	322.641	.393	84.864	% GAS VOL (DRY)
	NO2	.001	.038	294.719	.000	16.168	PPMV (DRY)
	O2	3.944	126.218	298.849	.038	7.700	% GAS VOL (DRY)
		----------	----------	---------	-------		
	TOTAL COMBUSTION GAS	59.603	1662.686	442.404	.736		
353	HEAT LOSS				.630		

	TOTAL HEAT RELEASED				1.366		
354	CO Hc AVAILABLE			4343.600	.000		
		==========	==========		=======		
	OVERALL TOTAL	59.603	1662.686		1.366		
	TOTAL DRY GAS	51.225	1511.751		.484		

COMBUSTION AIR SUMMARY

OPERATING CONDITIONS	UNIT 1
TEMPERATURE (F)	60.000
PRESSURE (IN. W.C.)	406.800
FLOW (ACFM)	347.494
AIR (DRY) TOTAL (LB/HR)	1584.964
AIR (DRY) THEORETICAL (LB/HR)	1040.639
AIR (DRY) TOT-THEO (LB/HR)	544.324
EXCESS AIR (%)	52.307
TOTAL O2 (LB/HR)	367.521
THEO. O2 (LB/HR)	241.303
TOT-THEO. O2 (LB/HR)	126.218
TOTAL N2 (LB/HR)	1217.442
THEO. N2 (LB/HR)	799.336
TOT-THEO. N2 (LB/HR)	418.106

COMBUSTION GAS SUMMARY	UNIT 1
TEMPERATURE (F)	1300.000
PRESSURE (IN. W.C.)	406.750
FLOW (ACFM)	1276.618

BASE CONDITIONS AND INCOMING GAS CONDITIONS	
ATMOSPHERIC PRESSURE (IN. H2O)	406.80
BASE TEMPERATURE (DEG F)	60.00
INLET GAS PRESSURE (IN. H2O)	406.75
INLET GAS TEMPERATURE (DEG F)	1300.00

PARTICULATE STANDARD INFORMATION	
PARTICULATE STANDARD BASIS	O2
PARTICULATE STANDARD BASIS CONCENTRATION (%)	7.00
PARTICULATE STANDARD BASIS CONDITION	DSCF
PARTICULATE STANDARD TEMPERATURE (DEG F)	68.00

UNIT NO	APC DEVICE	RECEIVER
1	PART. QUENCH	QUENCH SUMP
2	BAGHOUSE	DUSTCOLLECT
3	ID FAN	
4	STACK	

APC DEVICE INFORMATION	UNIT 1	UNIT 2	UNIT 3	UNIT 4
RECYCLE FLOW (GPM)	.00	.00	.00	.00
RECYCLE FLOW (LB/HR)	.00	.00	.00	.00
OUTLET PRESSURE (IN. H2O)	405.75	385.75	415.80	414.80
APC HEAT LOSS (MM BTU/HR)	.00	.00	.00	.00

PERCENT REMOVAL DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
ASH	.00	99.00	.00	.00
METAL SALTS	.00	99.00	.00	.00
ALKALI SALTS	.00	99.00	.00	.00

RECEIVER DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
REC. EXISTENCE	NO	YES	NO	NO
REC. PURGE DESTINATION	0	0	0	0
REC. PURGE TARGET	DIS	DIS	DIS	DIS
REC. SS REMOVAL EFFICIENCY	.00	.00	.00	.00
REC. HEAT LOSS (MM BTU/HR)	.00	.00	.00	.00

MAKEUP STREAM DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
MAKEUP OPTION	APC	APC	REC	REC
MAKEUP FLOW (GPM)	.65	.00	.00	.00
MAKEUP TDS (MG/L)	200.00	.00	.00	.00
MAKEUP TSS (MG/L)	.00	.00	.00	.00
MAKEUP TEMP. (DEG F)	60.00	60.00	60.00	60.00

NEUTRALIZATION STREAM DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
NEUT. OPTION	APC	APC	REC	REC
NEUT. REAGENT NAME	NAOH	NAOH	NAOH	NAOH
NEUT. REAG. TEMP. (DEG F)	60.00	60.00	60.00	60.00
NEUT. REAG. CONC. (%)	23.00	23.00	20.00	20.00
STOICHIOMETRIC RATIO	1.00	1.00	1.00	1.00

OPERATIONAL LIMITS DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
MIN. GAS OUT. TEMP. (DEG F)	0.	0.	0.	0.
PURGE TDS CONCENTRATION (%)	0.	0.	0.	0.
PURGE TSS CONCENTRATION (%)	0.	0.	0.	0.
PURGE ACID CONCENTRATION (%)	0.	0.	0.	0.

OTHER GAS DATA	GAS 1
NAME OF OTHER GAS	ATM AIR
FEED RATE (LB/HR)	163.00
TEMPERATURE (DEG F)	60.00
INPUT CODE	2.
DESTINATION UNIT NUMBER	1.

OTHER GAS COMP. DATA (LB/HR)	GAS 1
H2O	1.63
N2	123.96
O2	37.41

UNIT 1 PART. QUENCH

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
350 GAS FROM CIRC. BED/CYCLONE: 1300.0 DEG F, 406.8 IN. W.C.						
H2O	8.378	150.935	1666.941	.252	.100	LB H2O/LB DRY GAS
CO2	3.808	167.590	318.044	.053	7.434	% DRY GAS VOL
CO	.000	.011	326.009	.000	7.434	PPM DRY GAS VOL
N2	43.471	1217.895	322.641	.393	84.864	% DRY GAS VOL
NO2	.001	.038	294.719	.000	16.168	PPM DRY GAS VOL
O2	3.944	126.218	298.849	.038	7.700	% DRY GAS VOL
TOTAL FLUE GAS	59.603	1662.686		.736	.000	GR DSCF @ 7.0 % O2
738 ATM AIR: 60.0 DEG F						
H2O	.090	1.630	1059.900	.002	.010	LB H2O/LB DRY GAS
N2	4.425	123.962	.000	.000	79.101	% DRY GAS VOL
O2	1.169	37.409	.000	.000	20.899	% DRY GAS VOL
TOTAL GAS	5.684	163.000		.002	.000	GR DSCF @ 7.0 % O2
651 MAKEUP WATER: 60.0 DEG F						
H2O	18.028	324.801	.000	.000		
TDS	.001	.065	36.000	.000		
TOTAL MAKEUP	18.029	324.866		.000		
OVERALL TOTAL	83.316	2150.552		.737		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
650 GAS TO BAGHOUSE: 429.0 DEG F, 405.8 IN. W.C.						
H2O	26.497	477.366	1228.285	.586	.285	LB H2O/LB DRY GAS
CO2	3.808	167.590	81.816	.014	6.702	% DRY GAS VOL
CO	.000	.011	92.493	.000	6.703	PPM DRY GAS VOL
N2	47.896	1341.856	92.151	.124	84.297	% DRY GAS VOL
NO2	.001	.038	76.465	.000	14.576	PPM DRY GAS VOL
O2	5.113	163.626	83.064	.014	8.999	% DRY GAS VOL
TOTAL FLUE GAS	83.315	2150.487		.737	.000	GR DSCF @ 7.0 % O2
655 PURGE FROM PART. QUENCH: 429.0 DEG F						
ALKALI SALTS	.001	.065	99.639	.000	100.00000	WT %
TOTAL PURGE	.001	.065		.000	.00000	WT % TSS
OVERALL TOTAL	83.316	2150.552		.737		
DRY GAS TOTAL	56.819	1673.121		.151		

UNIT 2 BAGHOUSE

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
650 GAS FROM PART. QUENCH: 429.0 DEG F, 405.8 IN. W.C.						
H2O	26.497	477.366	1228.285	.586	.285	LB H2O/LB DRY GAS
CO2	3.808	167.590	81.816	.014	6.702	% DRY GAS VOL
CO	.000	.011	92.493	.000	6.703	PPM DRY GAS VOL
N2	47.896	1341.856	92.151	.124	84.297	% DRY GAS VOL
NO2	.001	.038	76.465	.000	14.576	PPM DRY GAS VOL
O2	5.113	163.626	83.064	.014	8.999	% DRY GAS VOL
TOTAL FLUE GAS	83.315	2150.487		.737	.000	GR DSCF @ 7.0 % O2
OVERALL TOTAL	83.315	2150.487		.737		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
661 GAS TO ID FAN: 429.0 DEG F, 385.8 IN. W.C.						
H2O	26.497	477.366	1228.285	.586	.285	LB H2O/LB DRY GAS
CO2	3.808	167.590	81.816	.014	6.702	% DRY GAS VOL
CO	.000	.011	92.493	.000	6.703	PPM DRY GAS VOL
N2	47.896	1341.856	92.151	.124	84.297	% DRY GAS VOL
NO2	.001	.038	76.465	.000	14.576	PPM DRY GAS VOL
O2	5.113	163.626	83.064	.014	8.999	% DRY GAS VOL
TOTAL FLUE GAS	83.315	2150.487		.737	.000	GR DSCF @ 7.0 % O2
OVERALL TOTAL	83.315	2150.487		.737		
DRY GAS TOTAL	56.819	1673.121		.151		

UNIT 2 DUSTCOLLECT

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION
OVERALL TOTAL	.000	.000		.000	

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION
OVERALL TOTAL	.000	.000		.000	

UNIT 3 ID FAN

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
661 GAS FROM BAGHOUSE: 429.0 DEG F, 385.8 IN. W.C.						
H2O	26.497	477.366	1228.285	.586	.285	LB H2O/LB DRY GAS
CO2	3.808	167.590	81.816	.014	6.702	% DRY GAS VOL
CO	.000	.011	92.493	.000	6.703	PPM DRY GAS VOL
N2	47.896	1341.856	92.151	.124	84.297	% DRY GAS VOL
NO2	.001	.038	76.465	.000	14.576	PPM DRY GAS VOL
O2	5.113	163.626	83.064	.014	8.999	% DRY GAS VOL
TOTAL FLUE GAS	83.315	2150.487		.737	.000	GR DSCF @ 7.0 % O2
682 HEAT OF COMPRESSION				.014		
OVERALL TOTAL	83.315	2150.487		.751		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
672 GAS TO STACK: 450.7 DEG F, 415.8 IN. W.C.						
H2O	26.497	477.366	1238.474	.591	.285	LB H2O/LB DRY GAS
CO2	3.808	167.590	87.078	.015	6.702	% DRY GAS VOL
CO	.000	.011	98.016	.000	6.703	PPM DRY GAS VOL
N2	47.896	1341.856	97.632	.131	84.297	% DRY GAS VOL
NO2	.001	.038	81.339	.000	14.576	PPM DRY GAS VOL
O2	5.113	163.626	88.110	.014	8.999	% DRY GAS VOL
TOTAL FLUE GAS	83.315	2150.487		.751	.000	GR DSCF @ 7.0 % O2
OVERALL TOTAL	83.315	2150.487		.751		
DRY GAS TOTAL	56.819	1673.121		.160		

UNIT 4 STACK

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
672 GAS FROM ID FAN: 450.7 DEG F, 415.8 IN. W.C.						
H2O	26.497	477.366	1238.474	.591	.285	LB H2O/LB DRY GAS
CO2	3.808	167.590	87.078	.015	6.702	% DRY GAS VOL
CO	.000	.011	98.016	.000	6.703	PPM DRY GAS VOL
N2	47.896	1341.856	97.632	.131	84.297	% DRY GAS VOL
NO2	.001	.038	81.339	.000	14.576	PPM DRY GAS VOL
O2	5.113	163.626	88.110	.014	8.999	% DRY GAS VOL
TOTAL FLUE GAS	83.315	2150.487		.751	.000	GR DSCF @ 7.0 % O2
OVERALL TOTAL	83.315	2150.487		.751		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
683 GAS TO ATMOSPHERE: 450.7 DEG F, 414.8 IN. W.C.						
H2O	26.497	477.366	1238.474	.591	.285	LB H2O/LB DRY GAS
CO2	3.808	167.590	87.078	.015	6.702	% DRY GAS VOL
CO	.000	.011	98.016	.000	6.703	PPM DRY GAS VOL
N2	47.896	1341.856	97.632	.131	84.297	% DRY GAS VOL
NO2	.001	.038	81.339	.000	14.576	PPM DRY GAS VOL
O2	5.113	163.626	88.110	.014	8.999	% DRY GAS VOL
TOTAL FLUE GAS	83.315	2150.487		.751	.000	GR DSCF @ 7.0 % O2
OVERALL TOTAL	83.315	2150.487		.751		
DRY GAS TOTAL	56.819	1673.121		.160		

GAS FLOW SUMMARY AT APC DEVICE OUTLET

UNIT NO	STREAM	TEMPERATURE (DEG F)	PRESSURE (IN. W.C.)	FLOW (ACFM)	DRY GAS (SCFM)
1	PART. QUENCH	429.0	405.8	903.496	364.906
2	BAGHOUSE	429.0	385.8	950.339	364.906
3	ID FAN	450.7	415.8	903.201	364.906
4	STACK	450.7	414.8	905.379	364.906

LIQUID FLOW SUMMARY

MAKEUP STREAMS TO:	FLOW (GAL/MIN)	H2O (LB/HR)	TEMP (DEG F)	D.S. (LB/HR)	S.S. (LB/HR)
PART. QUENCH	.650	324.801	60.000	.065	.000
TOTAL	.650	324.801		.065	.000

DISCHARGE PURGE: ORIGINATION SUMP	TEMP (DEG F)	H2O (LB/HR)	ORGANIC (LB/HR)	D.S. (LB/HR)	S.S. (LB/HR)	ACIDS (LB/HR)
PART. QUENCH	429.032	.000	.000	.065	.000	.000
TOTAL PURGE	.000	.000	.000	.065	.000	.000

UNIT NO	COMBUSTION DEVICE	BASE CONDITIONS			SPECIFIC HEAT (BTU/LB-F)	MOLECULAR WEIGHT (LB/LB-MOLE)
1	CIRC. BED/CYCLONE	ATM PRES (IN. H2O):	406.800	ASH	.270	100.000
		BASE TEMP (F):	60.000	MSALT	.270	100.000
		TOTAL NUMBER OF FUELS:	5	ASALT	.270	100.000
				FIXED CARBON	.220	12.011
				INERT	.270	100.000
				PYRO GAS	.500	100.000

COMBUSTION MODULE

OPERATING CONDITIONS	UNIT 1
EXIT GAS TEMPERATURE (F)	600.000
EXIT SOLID TEMPERATURE (F)	600.000
PRESSURE DROP (IN.W.C.)	.050
OUT PRESSURE (IN. W.C.)	406.750
RADIATION HEAT LOSS	.630
HEAT LOSS UNIT	MM BTU/HR
HEAT INPUT (MM BTU/HR)	.000
EXCESS AIR (%) FOR OXIDIZED WASTE	216.376
MINIMUM XS AIR (%) FOR OXIDIZED WASTE	.000
MINIMUM O2 (%) IN EXIT GAS	50.000
AIR TEMPERATURE TO BURNER (F)	60.000
AIR HUMIDITY (LB H2O/LB DRY AIR)	.010
EXCESS AIR FOR AUX FUEL (%)	.000
NAME OF AUXILIARY FUEL	NAT GAS
QUENCH CODE (1 AIR,2 H2O)	1
QUENCH H2O TEMPERATURE TO BURNER (F)	.000
ASH IN EXIT (%)	6.000
MSALT IN EXIT (%)	100.000
ASALT IN EXIT (%)	100.000
FIXED CARBON IN EXIT (%)	.000
CO/CO2 COMBUSTION EFFICIENCY (%)	99.990
FUEL NO2 EFFICIENCY (%)	2.500

ASH MODULE CONDITIONS	
EXIT STEAM DESTINATION	ATMOSPHERE
HEAT LOSS (MM BTU/HR)	.000
SOLID EXIT TEMPERATURE (F)	.000
QUENCH WATER (GPM)	.000
MOISTURE IN WET ASH (%)	.000
QUENCH H2O MAKEUP TEMPERATURE (F)	60.000
QUENCH H2O TSS (mg/l)	.000
QUENCH H2O TDS (mg/l)	.000

FUEL TO: CIRC. BED/CYCLONE (PER HOUR)

FUEL NAME		C	H2	O2	N2	H2O	CL2	S	P
		******	******	******	COMPONENT FLOW TO FURNACE	******	******	******	******
250	NAT GAS								
	PERCENT	73.928	24.431	.891	.750	.000	.000	.000	.000
	POUNDS	.000	.000	.000	.000	.000	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	.000	.000	.000	.000
251	NAT GAS								
	PERCENT	73.928	24.431	.891	.750	.000	.000	.000	.000
	POUNDS	39.182	12.948	.472	.398	.000	.000	.000	.000
	LB-MOLE	3.262	6.423	.015	.014	.000	.000	.000	.000
		--------	---------	----------	----------	----------	----------	----------	------------
TOT FUEL									
	POUNDS	39.182	12.948	.472	.398	.000	.000	.000	.000
	LB-MOLE	3.262	6.423	.015	.014	.000	.000	.000	.000

FUEL TO: CIRC. BED/CYCLONE (PER HOUR) (CONTINUED)

FUEL NAME ************************************** COMPONENT FLOW TO FURNACE **

FUEL NAME		SI	BR2	F2	ASH	MSALT	ASALT	F.CARB	INERTS
250 NAT GAS									
	PERCENT	.000	.000	.000	.000	.000	.000	.000	.000
	POUNDS	.000	.000	.000	.000	.000	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	.000	.000	.000	.000
251 NAT GAS									
	PERCENT	.000	.000	.000	.000	.000	.000	.000	.000
	POUNDS	.000	.000	.000	.000	.000	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	.000	.000	.000	.000
		--------	---------	----------	----------	----------	----------	----------	------------
TOT FUEL									
	POUNDS	.000	.000	.000	.000	.000	.000	.000	.000
	LB-MOLE	.000	.000	.000	.000	.000	.000	.000	.000

UNIT 1 CIRC. BED/CYCLONE

*** MASS AND ENERGY IN ***

	FUELS:	USE CODE	TEMP DEG F	LB/HR	BTU/LB	MM BTU/HR	% OF TOTAL HEAT DUTY
251	NAT GAS	OXD	60.00	53.000	21800.000	1.155	97.478146
351	COMBUSTION AIR						
	O2		60.00	653.948	.000	.000	.000000
	N2		60.00	2166.253	.000	.000	.000000
	H2O		60.00	28.202	1059.900	.030	2.521854
				==========		=======	==========
	OVERALL TOTAL			2901.404		1.185	100.000000

*** MASS AND ENERGY OUT ***

350 COMBUSTION GAS OUT 600.00 DEG F , 406.8 IN. W.C.

		LB-MOLES/HR	LB/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
	H2O	7.988	143.916	1309.449	.188	.052	LB H2O/LB DRY GAS
	CO2	3.262	143.557	124.339	.018	3.449	% GAS VOL (DRY)
	CO	.000	.009	136.334	.000	3.449	PPMV (DRY)
	N2	77.336	2166.641	135.602	.294	81.772	% GAS VOL (DRY)
	NO2	.001	.033	115.821	.000	7.501	PPMV (DRY)
	O2	13.977	447.249	123.298	.055	14.778	% GAS VOL (DRY)
		----------	----------	---------	-------		
	TOTAL COMBUSTION GAS	102.563	2901.404	191.373	.555		
353	HEAT LOSS				.630		

	TOTAL HEAT RELEASED				1.185		
354	CO Hc AVAILABLE			4343.600	.000		
		==========	==========		=======		
	OVERALL TOTAL	102.563	2901.404		1.185		
	TOTAL DRY GAS	94.575	2757.488		.367		

COMBUSTION AIR SUMMARY OPERATING CONDITIONS	UNIT 1
TEMPERATURE (F)	60.000
PRESSURE (IN. W.C.)	406.800
FLOW (ACFM)	618.312
AIR (DRY) TOTAL (LB/HR)	2820.202
AIR (DRY) THEORETICAL (LB/HR)	891.408
AIR (DRY) TOT-THEO (LB/HR)	1928.793
EXCESS AIR (%)	216.376
TOTAL O2 (LB/HR)	653.948
THEO. O2 (LB/HR)	206.700
TOT-THEO. O2 (LB/HR)	447.249
TOTAL N2 (LB/HR)	2166.253
THEO. N2 (LB/HR)	684.709
TOT-THEO. N2 (LB/HR)	1481.545

COMBUSTION GAS SUMMARY	UNIT 1
TEMPERATURE (F)	600.000
PRESSURE (IN. W.C.)	406.750
FLOW (ACFM)	1322.916

BASE CONDITIONS AND INCOMING GAS CONDITIONS	
ATMOSPHERIC PRESSURE (IN. H2O)	406.80
BASE TEMPERATURE (DEG F)	60.00
INLET GAS PRESSURE (IN. H2O)	406.75
INLET GAS TEMPERATURE (DEG F)	600.00

PARTICULATE STANDARD INFORMATION	
PARTICULATE STANDARD BASIS	O2
PARTICULATE STANDARD BASIS CONCENTRATION (%)	7.00
PARTICULATE STANDARD BASIS CONDITION	DSCF
PARTICULATE STANDARD TEMPERATURE (DEG F)	68.00

UNIT NO	APC DEVICE	RECEIVER
1	PART. QUENCH	QUENCH SUMP
2	BAGHOUSE	DUSTCOLLECT
3	ID FAN	
4	STACK	

APC DEVICE INFORMATION	UNIT 1	UNIT 2	UNIT 3	UNIT 4
RECYCLE FLOW (GPM)	.00	.00	.00	.00
RECYCLE FLOW (LB/HR)	.00	.00	.00	.00
OUTLET PRESSURE (IN. H2O)	405.75	385.75	415.80	414.80
APC HEAT LOSS (MM BTU/HR)	.00	.00	.00	.00

PERCENT REMOVAL DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
ASH	.00	99.00	.00	.00
METAL SALTS	.00	99.00	.00	.00
ALKALI SALTS	.00	99.00	.00	.00

RECEIVER DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
REC. EXISTENCE	NO	YES	NO	NO
REC. PURGE DESTINATION	0	0	0	0
REC. PURGE TARGET	DIS	DIS	DIS	DIS
REC. SS REMOVAL EFFICIENCY	.00	.00	.00	.00
REC. HEAT LOSS (MM BTU/HR)	.00	.00	.00	.00

MAKEUP STREAM DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
MAKEUP OPTION	APC	APC	REC	REC
MAKEUP FLOW (GPM)	.20	.00	.00	.00
MAKEUP TDS (MG/L)	200.00	.00	.00	.00
MAKEUP TSS (MG/L)	.00	.00	.00	.00
MAKEUP TEMP. (DEG F)	60.00	60.00	60.00	60.00

NEUTRALIZATION STREAM DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
NEUT. OPTION	APC	APC	REC	REC
NEUT. REAGENT NAME	NAOH	NAOH	NAOH	NAOH
NEUT. REAG. TEMP. (DEG F)	60.00	60.00	60.00	60.00
NEUT. REAG. CONC. (%)	23.00	23.00	20.00	20.00
STOICHIOMETRIC RATIO	1.00	1.00	1.00	1.00

OPERATIONAL LIMITS DATA	UNIT 1	UNIT 2	UNIT 3	UNIT 4
MIN. GAS OUT. TEMP. (DEG F)	0.	0.	0.	0.
PURGE TDS CONCENTRATION (%)	0.	0.	0.	0.
PURGE TSS CONCENTRATION (%)	0.	0.	0.	0.
PURGE ACID CONCENTRATION (%)	0.	0.	0.	0.

OTHER GAS DATA	GAS 1
NAME OF OTHER GAS	ATM AIR
FEED RATE (LB/HR)	50.00
TEMPERATURE (DEG F)	60.00
INPUT CODE	2.
DESTINATION UNIT NUMBER	1.

OTHER GAS COMP. DATA (LB/HR)	GAS 1
H2O	.50
N2	38.03
O2	11.48

UNIT 1 PART. QUENCH

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
350 GAS FROM CIRC. BED/CYCLONE: 600.0 DEG F, 406.8 IN. W.C.						
H2O	7.988	143.916	1309.449	.188	.052	LB H2O/LB DRY GAS
CO2	3.262	143.557	124.339	.018	3.449	% DRY GAS VOL
CO	.000	.009	136.334	.000	3.449	PPM DRY GAS VOL
N2	77.336	2166.641	135.602	.294	81.772	% DRY GAS VOL
NO2	.001	.033	115.821	.000	7.501	PPM DRY GAS VOL
O2	13.977	447.249	123.298	.055	14.778	% DRY GAS VOL
TOTAL FLUE GAS	102.563	2901.404		.555	.000	GR DSCF @ 7.0 % O2
738 ATM AIR: 60.0 DEG F						
H2O	.028	.500	1059.900	.001	.010	LB H2O/LB DRY GAS
N2	1.357	38.025	.000	.000	79.101	% DRY GAS VOL
O2	.359	11.475	.000	.000	20.899	% DRY GAS VOL
TOTAL GAS	1.744	50.000		.001	.000	GR DSCF @ 7.0 % O2
651 MAKEUP WATER: 60.0 DEG F						
H2O	5.547	99.939	.000	.000		
TDS	.000	.020	36.000	.000		
TOTAL MAKEUP	5.547	99.959		.000		
OVERALL TOTAL	109.854	3051.362		.556		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
650 GAS TO BAGHOUSE: 432.3 DEG F, 405.8 IN. W.C.						
H2O	13.563	244.355	1229.803	.301	.087	LB H2O/LB DRY GAS
CO2	3.262	143.557	82.599	.012	3.387	% DRY GAS VOL
CO	.000	.009	93.316	.000	3.388	PPM DRY GAS VOL
N2	78.693	2204.666	92.968	.205	81.724	% DRY GAS VOL
NO2	.001	.033	77.190	.000	7.367	PPM DRY GAS VOL
O2	14.335	458.724	83.815	.038	14.887	% DRY GAS VOL
TOTAL FLUE GAS	109.854	3051.342		.556	.000	GR DSCF @ 7.0 % O2
655 PURGE FROM PART. QUENCH: 432.3 DEG F						
ALKALI SALTS	.000	.020	100.513	.000	100.00000	WT %
TOTAL PURGE	.000	.020		.000	.00000	WT % TSS
OVERALL TOTAL	109.854	3051.362		.556		
DRY GAS TOTAL	96.291	2806.988		.255		

UNIT 2 BAGHOUSE

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
650 GAS FROM PART. QUENCH: 432.3 DEG F, 405.8 IN. W.C.						
H2O	13.563	244.355	1229.803	.301	.087	LB H2O/LB DRY GAS
CO2	3.262	143.557	82.599	.012	3.387	% DRY GAS VOL
CO	.000	.009	93.316	.000	3.388	PPM DRY GAS VOL
N2	78.693	2204.666	92.968	.205	81.724	% DRY GAS VOL
NO2	.001	.033	77.190	.000	7.367	PPM DRY GAS VOL
O2	14.335	458.724	83.815	.038	14.887	% DRY GAS VOL
TOTAL FLUE GAS	109.854	3051.342		.556	.000	GR DSCF @ 7.0 % O2
OVERALL TOTAL	109.854	3051.342		.556		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
661 GAS TO ID FAN: 432.3 DEG F, 385.8 IN. W.C.						
H2O	13.563	244.355	1229.803	.301	.087	LB H2O/LB DRY GAS
CO2	3.262	143.557	82.599	.012	3.387	% DRY GAS VOL
CO	.000	.009	93.316	.000	3.388	PPM DRY GAS VOL
N2	78.693	2204.666	92.968	.205	81.724	% DRY GAS VOL
NO2	.001	.033	77.190	.000	7.367	PPM DRY GAS VOL
O2	14.335	458.724	83.815	.038	14.887	% DRY GAS VOL
TOTAL FLUE GAS	109.854	3051.342		.556	.000	GR DSCF @ 7.0 % O2
OVERALL TOTAL	109.854	3051.342		.556		
DRY GAS TOTAL	96.291	2806.988		.255		

UNIT 2 DUSTCOLLECT

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION
OVERALL TOTAL	.000	.000		.000	

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION
OVERALL TOTAL	.000	.000		.000	

UNIT 3 ID FAN

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
661 GAS FROM BAGHOUSE: 432.3 DEG F, 385.8 IN. W.C.						
H2O	13.563	244.355	1229.803	.301	.087	LB H2O/LB DRY GAS
CO2	3.262	143.557	82.599	.012	3.387	% DRY GAS VOL
CO	.000	.009	93.316	.000	3.388	PPM DRY GAS VOL
N2	78.693	2204.666	92.968	.205	81.724	% DRY GAS VOL
NO2	.001	.033	77.190	.000	7.367	PPM DRY GAS VOL
O2	14.335	458.724	83.815	.038	14.887	% DRY GAS VOL
TOTAL FLUE GAS	109.854	3051.342		.556	.000	GR DSCF @ 7.0 % O2
682 HEAT OF COMPRESSION				.018		
OVERALL TOTAL	109.854	3051.342		.574		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
672 GAS TO STACK: 455.0 DEG F, 415.8 IN. W.C.						
H2O	13.563	244.355	1240.451	.303	.087	LB H2O/LB DRY GAS
CO2	3.262	143.557	88.102	.013	3.387	% DRY GAS VOL
CO	.000	.009	99.086	.000	3.388	PPM DRY GAS VOL
N2	78.693	2204.666	98.694	.218	81.724	% DRY GAS VOL
NO2	.001	.033	82.288	.000	7.367	PPM DRY GAS VOL
O2	14.335	458.724	89.089	.041	14.887	% DRY GAS VOL
TOTAL FLUE GAS	109.854	3051.342		.574	.000	GR DSCF @ 7.0 % O2
OVERALL TOTAL	109.854	3051.342		.574		
DRY GAS TOTAL	96.291	2806.988		.271		

UNIT 4 STACK

** MASS AND ENERGY IN **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
672 GAS FROM ID FAN: 455.0 DEG F, 415.8 IN. W.C.						
H2O	13.563	244.355	1240.451	.303	.087	LB H2O/LB DRY GAS
CO2	3.262	143.557	88.102	.013	3.387	% DRY GAS VOL
CO	.000	.009	99.086	.000	3.388	PPM DRY GAS VOL
N2	78.693	2204.666	98.694	.218	81.724	% DRY GAS VOL
NO2	.001	.033	82.288	.000	7.367	PPM DRY GAS VOL
O2	14.335	458.724	89.089	.041	14.887	% DRY GAS VOL
TOTAL FLUE GAS	109.854	3051.342		.574	.000	GR DSCF @ 7.0 % O2
OVERALL TOTAL	109.854	3051.342		.574		

** MASS AND ENERGY OUT **	LB-MOLES/HR	LBS/HR	BTU/LB	MM BTU/HR	CONCENTRATION	
683 GAS TO ATMOSPHERE: 455.0 DEG F, 414.8 IN. W.C.						
H2O	13.563	244.355	1240.451	.303	.087	LB H2O/LB DRY GAS
CO2	3.262	143.557	88.102	.013	3.387	% DRY GAS VOL
CO	.000	.009	99.086	.000	3.388	PPM DRY GAS VOL
N2	78.693	2204.666	98.694	.218	81.724	% DRY GAS VOL
NO2	.001	.033	82.288	.000	7.367	PPM DRY GAS VOL
O2	14.335	458.724	89.089	.041	14.887	% DRY GAS VOL
TOTAL FLUE GAS	109.854	3051.342		.574	.000	GR DSCF @ 7.0 % O2
OVERALL TOTAL	109.854	3051.342		.574		
DRY GAS TOTAL	96.291	2806.988		.271		

GAS FLOW SUMMARY AT APC DEVICE OUTLET

UNIT NO	STREAM	TEMPERATURE (DEG F)	PRESSURE (IN. W.C.)	FLOW (ACFM)	DRY GAS (SCFM)
1	PART. QUENCH	432.3	405.8	1195.635	618.411
2	BAGHOUSE	432.3	385.8	1257.625	618.411
3	ID FAN	455.0	415.8	1196.404	618.411
4	STACK	455.0	414.8	1199.288	618.411

LIQUID FLOW SUMMARY

MAKEUP STREAMS TO:	FLOW (GAL/MIN)	H2O (LB/HR)	TEMP (DEG F)	D.S. (LB/HR)	S.S. (LB/HR)
PART. QUENCH	.200	99.939	60.000	.020	.000
TOTAL	.200	99.939		.020	.000

DISCHARGE PURGE: ORIGINATION SUMP	TEMP (DEG F)	H2O (LB/HR)	ORGANIC (LB/HR)	D.S. (LB/HR)	S.S. (LB/HR)	ACIDS (LB/HR)
PART. QUENCH	432.272	.000	.000	.020	.000	.000
TOTAL PURGE	.000	.000	.000	.020	.000	.000

13.0 PILOT PLANT COST ESTIMATE

13.0 Pilot Plant Cost Estimate

The pilot plant cost estimate includes the equipment purchase costs, integration costs, installation costs, process and detail engineering costs, and construction advice costs (Table 13-1). The summary cost sheets for each of these items are attached. Vendor quotations for major equipment are included in this chapter.

This cost estimate has an accuracy of plus or minus 20 percent. More accurate costs can be gathered during the detail design phase.

Table 13-1

Summary of CBC Pilot Plant Price

Item(s)	Total Price ($)
Total Equipment	$805,222
Trailers	$220,800
Infrastructure	$676,370
Process Engineering	$51,875
Detail Design Engineering	$206,587
Project Management	$144,855
Construction Advice	$51,757
TOTAL BASE PRICE	$2,157,466
Optional Building Price	
Building	$122,400
TOTAL	$2,279,866

USAEC Pilot Plant Cost Estimate

	Cost						Price					
	Labor Cost	Equipment, Material, & Subcont.	Travel & Misc.	Indirect Cost	Subcon. OH & P	Subtotal Cost	Labor Price	Equipment Mat & Sub	Travel Price	Indirects	Subcon. OH & P	Total Price
							3.2	1.2	1.2	1.2	1.2	
Total Equipment		$506,612		$103,905	$60,501	$671,018		$607,934		$124,686	$72,601	$805,222
Trailers		$184,000				$184,000		$220,800				$220,800
Infrastructure		$425,544		$87,278	$50,820	$563,642		$510,653		$104,734	$60,984	$676,370
Process engineering	$16,211					$16,211	$51,875					$51,875
Detail Design Engineering	$63,447		$2,964			$66,411	$203,030		$3,557			$206,587
Project Management	$39,560		$15,219			$54,779	$126,592		$18,263			$144,855
Construction Advice	$12,124		$10,800			$22,924	$38,797		$12,960			$51,757
Total Base Cost	$131,342	$1,116,156	$28,983	$191,183	$111,321	$1,578,985	$420,294	$1,339,387	$34,780	$229,420	$133,585	$2,157,466
Optional Building		$102,000				$102,000		$122,400				$122,400
Total	$131,342	$1,218,156	$28,983	$191,183	$111,321	$1,680,985	$420,294	$1,461,787	$34,780	$229,420	$133,585	$2,279,866

USACE/CBC
PROJECT # 322423.002.03.005
ESTIMATOR: FHG CHECKED: PCL
SCOPE /PFD's & P& ID's

11/09/94

ITEM	QTY.	UNIT	MATERIAL COST	LABOR HRS	LABOR COST	OTHER COSTS & SUBCONTR.	TOTAL COST
B-2001- COMBUSTION AIR BLOWER	1	EA	$5,048	32	$1,355	$5,000	$11,403
B-2002-PURGE AIR BLOWER	1	EA	$1,488	32	$1,355		$2,843
B-5001-ID FAN	1	EA	$15,600	120	$5,082		$20,682
F-2001- COMBUSTOR	1	EA	$65,000	80	$3,388		$68,388
F-2002- CYCLONE SEPARATOR	1	EA	$15,745	40	$1,694		$17,439
G-2001- STARTUP BURNER	1	EA	$25,000	24	$1,016		$26,016
H-2001- ASH CONVEYOR-WATER COOLED	1	EA	$50,000	60	$2,541		$52,541
H-2002-HOPPER FOR LIMESTONE	1	EA	$1,200	8	$339		$1,539
H-2003-SCREW CONVEYOR-FOR LIMESTONE	1	EA	$12,500	48	$2,033		$14,533
H-2004-HOPPER FOR ALUMINUM OXIDE	1	EA	$1,200	8	$339		$1,539
H-2005-SCREW CONVEYOR-FOR ALUMINUM OXIDE	1	EA	$12,500	48	$2,033		$14,533
H-2006- HOIST -5 TON FOR MOVEMENT IN THREE PLANES	1	EA	$30,000	60	$2,541		$32,541
H-2007-BAG BREAKER w/ DUST ENCLOSURE FOR LIMESTONE	1	EA	$3,500	24	$1,016		$4,516
H-2008-BAG BREAKER w/ DUST ENCLOSURE FOR ALUMINUM OXIDE	1	EA	$3,500	24	$1,016		$4,516
P-2001- PUMP RECIRCULATING-10 GPM-5' HEAD	1	EA	$225	8	$339		$564
T-5001- PARTIAL QUENCH	1	EA	$30,000	120	$5,082		$35,082
H-5001-ROTARY AIRLOCK	1	EA	$7,000	16	$678		$7,678
S-5001- BAGHOUSE	1	EA	$105,000	80	$3,388		$108,388
H-5002 ROTARY AIRLOCK	1	EA	$6,000	16	$678		$6,678
Z-5001-STACK	1	EA	$25,000	60	$2,541		$27,541
ASH DRUM (TAG DUPLICATED AS T-2001)-ALLOWANCE	1	EA	$5,000	8	$339		$5,339
SUBTOTAL EQUIPMENT	1	LS	$420,506	916	$38,793	$5,000	$464,299
ALLOWANCE UNIDENTIFIED EQUIPMENT (2% OF EQUIPMENT COST)	1	EA				$9,286	$9,286
ALLOWANCE OFF LOAD/SETTING.(2% OF EQUIPMENT COST)	1	EA		221		$9,286	$9,286
FREIGHT ALLOWANCE (5% OF EQUIPMENT COST)	1	EA				$21,025	$21,025
WORKMEN'S COMPENSATION(7% OF LABOR COSTS)	1	EA				$2,716	$2,716
TOTAL ADJUSTED PURCHASED EQUPMENT COSTS	1	LS	$420,506	1,137	$38,793	$47,313	$506,612

USACE/CBC
PROJECT # 322423.002.03.005
ESTIMATOR: FHG CHECKED: PCL
SCOPE /PFD's & P& ID's

11/09/94

ITEM	QTY.	UNIT	MATERIAL COST	LABOR HRS	LABOR COST	OTHER COSTS & SUBCONTR.	TOTAL COST
ADJUSTED PURCHASED EQUIPMENT COST	1	LS	$420,506	1,137	$38,793	$47,313	$506,612
INFRASTRUCTURE COSTS							
SITE PREPARATION & SITE IMPROVEMENT	1	LS				$50,661	$50,661
CONCRETE- 5% OF ADJUSTED PURCH.EQPT.COSTS	1	LS				$25,331	$25,331
STRUCTURAL STEEL- 4% OF ADJUSTED PURCH.EQPT.COSTS	1	LS	$8,106	263	$11,145	$1,013	$20,264
ABOVEGROUND PIPING -15% OF ADJUSTED PURCH.EQPT.COSTS	1	LS	$45,595	628	$26,597	$3,800	$75,992
ABOVEGROUND ELECTRICAL- 10% OF ADJUSTED PURCH.EQPT.COSTS	1	LS	$32,930	359	$15,198	$2,533	$50,661
ABOVEGROUND DUCTWORK- 6% OF ADJUSTED PURCH.EQPT.COSTS	1	LS	$19,758	215	$9,119	$1,520	$30,397
INSTRUMENTATION	1	LS	$90,860	1,306	$35,915	$10,000	$136,775
INSULATION- 4% OF ADJUSTED PURCH.EQUPT.COSTS	1	LS	$12,159	191	$8,106		$20,265
PAINTING-3% OF ADJUSTED PURCH.EQPT.COSTS	1	LS	$6,079	215	$9,119		$15,198
SUBTOTAL: INFRASTRUCTURE COSTS.	1	LS	$215,487	3,178	$115,199	$94,858	$425,544
TOTAL DIRECT COSTS.	1	LS	$635,993	4,315	$153,992	$142,171	$932,156
INDIRECT COSTS	1	LS					
SPARES-2% OF TOTAL ADJUSTED PUR.EQUPT.COSTS	1	LS	$8,410				$8,410
CHERRY PICKER-(2 WEEKS RENTAL)	1	LS		80	$3,388	$1,200	$4,588
TRUCK-- 8 WEEKS RENTAL	1	LS		320	$13,552	$2,800	$16,352
MISCELLANEOUS EQUIPMENT RENTAL-8 WEEKS & CONSUMMABLES	1	LS				$1,600	$1,600
CONSUMMABLES-2% OF ADJUSTED PURCH. EQUPT. COSTS	1	LS	$8,410		$776	$946	$10,132
SALARY OF INDIRECT PERSONNEL(8 WEEKS DURATION)-4 PEOPLE	1	LS			$44,800	$6,720	$51,520
CONSTRUCTION FACILITIES (8 WEEKS RENTAL)	1	LS				$8,000	$8,000
OTHER INDIRECTS (1/2% OF TOTAL DIRECT COSTS)	1	LS	$3,180		$770	$711	$4,661
BONDING (3% OF TOTAL DIRECT COSTS)	1	LS				$27,965	$27,965
TAXES(5% OF ADJ.PURCH EQUIPMENT COSTS)	1	LS	$21,025				$21,025
HEALTH & SAFETY(FIGURE 20 CRAFTSMEN - 8WEEKS & ONE INSTRUCTOR FOR 8 WEEKS	1	LS			$23,100	$5,775	$28,875
WARRANTY COSTS(2% OF ADJ. PURCH. EQUPT. COSTS)	1	LS	$8,410				$8,410
SUBTOTAL INDIRECT COSTS.	1	LS	$49,435	400	$86,386	$55,717	$191,538
TOTAL CONTRACT COSTS.	1	LS	$685,428	4,715	$240,378	$197,888	$1,123,694
PROFIT & OVERHEAD OF CONSTRUCTION CONTRACTOR-10% ON TOTAL	1	LS	$68,543		$24,038	$19,789	$112,370
TOTAL CONSTRUCTION PRICE	1	LS	$753,971	4,715	$264,416	$217,677	$1,236,064

USACE/CBC
PROJECT # 322423.002.03.005
ESTIMATOR: FHG CHECKED: PCL
SCOPE /PFD's & P& ID's

11/09/94

ITEM	QTY.	UNIT	MATERIAL COST	LABOR HRS	LABOR COST	OTHER COSTS & SUBCONTR.	TOTAL COST
TOTAL CONSTRUCTION PRICE	1	LS	$753,971	4,715	$264,416	$217,677	$1,236,064
PROJ. MGT., ENGINEERING & CONSTRUCTION ADVICE	1	LS					
PROCESS ENGINEERING(BARE COSTS)	1	LS			$16,211		$16,211
DETAIL DESIGN ENGINEERING(BARE COSTS)	1	LS			$63,447	$2,964	$66,411
PROJECT MANAGEMENT(BARE COSTS)	1	LS			$39,560	$15,219	$54,779
CONSTRUCTION ADVICE(BARE COSTS)	1	LS			$12,124	$10,800	$22,924
TOTAL PROJ. MGT., ENGINEERING & CONSTRUCTION ADVICE	1	LS			$131,342	$28,983	$160,325
TRAILER COSTS-8' WIDE X40 FT. LONG(FURNISH ONLY)	8	EACH	$184,000				$184,000
TOTAL PROJECT COSTS.	1	LS	$937,971		$395,758	$246,660	$1,580,389
OPTION-BUILDING PREFABRICATED BUTLER TYPE-120'LONG X50' W X 50' H w/WINDOW HVAC UNIT, ONE PERSONNEL DOOR & ONE 24' X 20' MOTORIZED EQUIPMENT DOOR.. NO FLOOR IN SCOPE /PRAKASH(SUBCONTRACTED)	1	LS	$102,000				$102,000

IT CORPORATION - ES / SE DIVISION
ENGINEERING ESTIMATE SUMMARY

RWW - 9/26/94

AREA NO: ALL PROJECT NAME: US - AEC JOB NUMBER: 322243 LABOR MARK-UP: 3.5	PLANT AREAS				ENGINEERING HOURS PER DOCUMENT (@ BARE COST OF :)					TOTAL COST	COMMENTS
					$13.50	$20.00	$24.13	$29.23	$36.00		
DELIVERABLES	FEED	THERMAL	GCS	TOTAL	CADD	E5	E8	E10	E11		
PROCESS DESIGN PHASE											
ANALYTICAL TESTING OF WASTE STREAMS											
OTHER MATERIAL TESTING (handling, dewatering, e											
TECHNICAL BASELINE DOCUMENT					16		60		20		
INTERFACE SPECIFICATION					16		60				
WASTE CHARACTERIZATION (# of streams)							6	12	2		HOURS ARE PER WASTE STREAM
HMB's				3			2	1	1	$1,192	HOURS ARE PER RUN
10 PFD's				1	48		20	20	2	$8,255	
11 P & ID's	1	1	1	3	48		20	20	2	$18,786	
PROCESS DESCRIPTION	1	1	1	3	4			8	1	$3,400	ONE P.D. PER AREA
PROCESS CONTROL DESCRIPTION	1	1	1	3	4			12	2	$5,006	ONE P.C.D. PER AREA
INSTRUMENT LIST				1							WITH PFD's/P&ID's
EQUIPMENT LIST				1							WITH PFD's/P&ID's
EQUIPMENT DUTY SPEC'S	4	10	10	24	1		2	2		$10,098	CUT-SHEET FORMAT
MAJOR EQUIPMENT BID SPEC's	1	1	2	4	4		8	16	4	$12,022	1-FEED,1-THERMAL,1-GCS, 1-CEM
SUBTOTAL PROCESS DESIGN										$56,739	
DETAIL DESIGN PHASE											
01 DRAWING INDEX				1	20					$945	
02 PLOT PLAN & EQUIPMENT LOCATION				5	48		24	16		$29,659	1-PLAN VIEW, 4 - ELEVATIONS
04 SHIPPING LISTS											
20 CODE VESSELS					8		4		1		
21 NON-CODED VESSELS & EQUIPMENT					8		4		1		BY VENDOR
24 BURNERS & MISC. MECHANICAL					16		4		1		BY VENDOR
40 QUOTE DWGS.					16		8		1		
50 PIPING PLANS & ELEVATIONS	2	4	2	8	15		4		1	$9,381	
51 PIPING SPOOLS					4		1				LET FAB SHOP GENERATE THESE IF POSSIBLE
61 ELECTRICAL ONE-LINE DIAGRAMS				1	8	16		2	1	$1,829	
62 SWITCHRACK ASSY					8	2			1		
63 MOTOR STARTER SCHEDULE					6	1			1		NOT REQ'D IF USE MFG. STD.
64 MOTOR CONTROL SCHEMATICS					16	8		2	1		
65 PANELBOARD SCHEMATIC / SCHEDULE					6	2					
66 CONDUIT ROUTING					8	4					DO NOT INCLUDE DETAILED B/M'S,
67 HEAT TRACE ROUTING					4	2					
68 CABLE SCHEDULES				1	8	2				$518	MAINTAIN DATABASE ONLY
69 CONDUIT DETAILS					8	8		1	1		ONE TYPICAL DRAWING OR PUT INTO SPEC's
71 ALARM & SHUTDOWN SCHEDULE				1	8			4	2	$1,039	GENERATE ONLY FOR WFT's & TRV's
72 CONTROL PANEL ASSY				4	32	16		4	1	$12,669	
73 PANEL WIRING SCHEMATICS				15	16	16		4	0.5	$35,223	
74 INTERCONNECT WIRING DIAGRAMS				10	12	12		2	0.5	$16,746	
75 LOOP DIAGRAMS				10	2			1		$1,968	GENERATE IF CAD SOFTWARE IS AUTOMATED
76 PROCESS LOGICS OR EQUAL	1	4	2	7	12	12		8	1	$16,460	
77 ANALOG FUNCTIONAL DIAGRAMS	1	2	1	4	12	8		4	1	$8,649	
78 INSTRUMENT INSTALLATION DETAILS					8	8		1	1		ONE TYPICAL DRAWING OR PUT INTO SPEC's
80 CIVIL					11			2			
81 FOUNDATION DETAILS											
90 STRUCTURAL	3	6	4	13	4			1		$3,787	ANCHOR BOLTS, LADDERS, PLATFORMS,ETC
V VENDOR DRAWINGS					1			1	1		
SUBTOTAL DETAIL DESIGN DRAWINGS										$136,873	
OTHER DETAIL DESIGN PRODUCTS											
INSTRUMENT SPEC'S	15	50	30	95		2.5		0.5		$21,484	
EQUIPMENT SPEC'S											
ELECTRICAL SPECS	5	25	8	38		4		2		$18,415	
MISCELLANEOUS SPEC'S	5	25	10	40		4		2		$19,384	
PLC PROGRAMMING (# of networks)											
MMI & ALARMS PROGRAMMING (# of screens)											
START-UP & OPERATIONS MANUAL				1	120	120		24		$16,525	
MECHANICAL DATA BOOKS				1	80	80				$9,380	
SUBTOTAL OTHER DESIGN PRODUCTS										$85,189	
TOTAL ENGINEERING										$278,801	

U.S. Army Environmental Center - CBC Estimate
PROJECT MANAGEMENT COST

CLIENT: USAEC
PROPOSAL: 322423.002.03.005

MANPOWER	ESTIMATED HOURS	DIRECT RATE	DIRECT COST
PROJECT MGMT - CMC	40	$41.00	$1,640
PROJECT MANAGEMENT	320	$35.00	$11,200
COST & SCHEDULING	40	$33.00	$1,320
PROJECT ADMINISTRATOR	100	$30.00	$3,000
PROJECT ENGINEER	160	$30.00	$4,800
PROCUREMENT / EXPEDITING	160	$30.00	$4,800
PROJECT COORDINATOR	160	$24.00	$3,840
DOCUMENT CONTROL/PRODUCTION	80	$24.00	$1,920
ADMINISTRATION / SECRETARIAL	160	$8.00	$1,280
PRODUCE OPERATING MANUALS	80	$24.00	$1,920
AS-BUILT DRAWINGS	160	$24.00	$3,840
Subtotal	1,460	303	$39,560

COMPUTER USAGE			
COMPUTER USAGE CHARGES	365	$6.08	$2,219

EXPENSES		DIRECT COST
TRAVEL & EXP-PROJ MGMT & ENG (5 TRIPS)	LUMP SUM @ 1,000/ TRIP	$5,000
SOURCE INSPECTION - DOMESTIC (5 TRIPS)	LUMP SUM @ $1,000 / TRIP	$5,000
OFFICE EXPENSES	ESTIMATE	$3,000
PROJECT MANAGEMENT EXPENSES		$13,000

TOTAL PROJECT MANAGEMENT COST	$54,779

U.S. Army Environmental Center - CBC Estimate

CONSTRUCTION / INSTALLATION ADVICE

CLIENT: USAEC
PROPOSAL: 322423.002.03.005

Installation & Construction Advice

	Men	Hrs/Wk	Wks/Mo	Units		Unit Cost	Total Labor	Total Other
LABOR	1	40	4.33	2	mos	$35	$12,124	
MEALS	1			2	mos	$1,050		$2,100
AIRFARE	1			2	trips	$1,800		$3,600
LODGING	1			2	mos	$1,800		$3,600
MISC.	1			2	mos	$750		$1,500
							$12,124	$10,800

USACE-CBC PROJECT
PROJECT # 322243.002.03.005
EQUIPMENT COSTS
SCOPE PER P &ID DWG 322243-20-11-001 REV A, 322243-20-11-002 REV A, & 322243-50-11-001 REV A

ITEM NO.	ITEM.	QTY.	UNIT	MATERIAL COSTS	LABOR HOURS	LABOR COSTS	OTHER COSTS	TOTAL COSTS
53	TAHH-PANEL MOUNT	3	EA	$795	12	$300		$1,095
54	TSHH-PANEL MOUNT	3	EA	$795	12	$300		$1,095
55	TIC-PANEL MOUNT	4	EA	$1,060	16	$400		$1,460
56	FAL-PANEL MOUNT	2	EA	$530	8	$200		$730
57	FSL-PANEL MOUNT	1	EA	$265	4	$100		$365
58	PAL-PANEL MOUNT	2	EA	$530	8	$200		$730
59	PAHH-PANEL MOUNT	3	EA	$795	12	$300		$1,095
60	PSHH-PANEL MOUNT	1	EA	$265	4	$100		$365
61	BALL-PANEL MOUNT	1	EA	$285	4	$100		$385
62	BSLL-PANEL MOUNT	1	EA	$285	4	$100		$385
63	TALL-PANEL MOUNT'	2	EA	$590	8	$200		$790
64	TSLL-PANEL MOUNT	2	EA	$590	8	$200		$790
65	TY-PANEL MOUNT	3	EA	$885	12	$300		$1,185
66	TI's-PANEL MOUNT	5	EA	$1,275	20	$500		$1,775
67	ISHH-PANEL MOUNT	1	EA	$255	4	$100		$355
68	IAHH-PANEL MOUNT	1	EA	$265	4	$100		$365
69	II-PANEL MOUNT	1	EA	$235	4	$100		$335
70	PSLL-PANEL MOUNT	2	EA	$510	8	$200		$710
71	PDIC-PANEL MOUNT	1	EA	$255	4	$100		$355
72	FIC-PANEL MOUNT	1	EA	$255	4	$100		$355
73	FY-PANEL MOUNT	1	EA	$255	4	$100		$355
74	PDI-PANEL MOUNT	1	EA	$255	4	$100		$355
75	FALL-PANELMOUNT	4	EA	$1,020	16	$400		$1,420
76	FSLL-PANEL MOUNT	3	EA	$765	12	$300		$1,065
77	FR-PANEL MOUNT	3	EA	$765	12	$300		$1,065
78	PAH-PANEL MOUNT	1	EA	$255	4	$100		$355
	TOTAL-INSTRUMENTS	242	EA	$49,825	822	$20,550	$10,000	$80,375
	WIRING & CABLE TRAY	1	LS	$15,150	202	$5,050		$20,200
	TUBING ALLOWANCE	1	LS	$17,625	282	$7,050		$24,675
	TOTAL COSTS	1	LS	$82,600	1,306	$32,650	$10,000	$125,250
	OVERHEAD & PROFIT @ 10% OF LB'R & MAT'L			$8,260		$3,265		$11,525
	TOTAL PRICE			$90,860		$35,915	$10,000	$136,775

*:- PANEL MTD INSTRUMENT PRICES REFLECT COST OF PANEL IN THEIR PRICE (APPORTIONED)

CHARLES F. SEXTON COMPANY
Manufacturers' Representatives - Mechanical Equipment
SUITE A, 6426 BAUM DR.
KNOXVILLE, TENNESSEE 37919
"Serving the Tennessee Valley Since 1930"

POST OFFICE BOX 10707
ZIP 37939-0707

TELEPHONE 615-588-9691
FACSIMILE 615-588-9692

FACSIMILE TRANSMISSION

Attn: Firoze Gaslightwala
Company: IT
From: Charlie Sexton
Date: 9/13/94
Page 1 of 1 (including this page)

Reference: Your 9/13 Fax

Firoze, on this fax I'm quoting Spencer, because the ratings fit them better than Buffalo.

Combustion Air
B-2001 - 6000 CFM @ 30" at std. density, Spencer Size 1550SS with 60 HP motor (actually rated 40" but can be dampered - $5048

Purge Air
B-2002 - 200 CFM @ 30" at std. density, Spencer Size 1002SS with 3 HP motor (actually rated 29.9") - $1488

ID Fan
B-5001 - 6000 CFM @ -60" at std. density, Spencer Size 45-4RB with 75 HP motor (may be able to use <75 HP motor, but can't check it out in less than about 2 days) - $15600 (this price should be okay regardless of what we have to do).

690-3626
Susanne

Alloy Fabrications

121 Peaks Station Rd.
Clinton, Tennessee 37716
(615) 457-2717
FAX (615) 457-2568

F-2001

SEPTEMBER 14, 1994

IT CORPORATION
312 DIRECTORS DRIVE
KNOXVILLE, TN 37923
ATTN: MR. FIROTE

GENTLEMEN:

THIS QUOTATION COVERS LABOR AND MATERIAL TO FABRICATE COMBUSTOR FROM CARBON STEEL WITH A HASTELLOY C-276 TUBE SHEET.

1. COMBUSTOR INCLUDING 16" AND 28" DUCT AND CONE BOTTOM VESSEL

   PRICE - FOB CLINTON, TN ---------------------------- $ 22,800.00

2. HASTELLOY C-276 2 1/2" THICK X 41" OD WITH HOLES. LABOR NOT INCLUDED IN THIS ITEM. NUMBER OF HOLES UNKNOWN.

   PRICE - FOB CLINTON, TN (MATERIAL ONLY) ------------ $ 16,800.00

3. 3" THICK HASTELLOY C-276 NOT AVAILABLE EXCEPT IN A FORGING. PRICE NOT AVAILABLE AT THIS TIME.

IF THERE ARE ANY QUESTIONS, PLEASE CONTACT ME AT THE ABOVE NUMBER.

SINCERELY,

Jim Irons
JIM IRONS

9/14/94

GOT REFRACTOR QUOTE (VERBAL - sent
FAX to MR CURTIS GILMAN @ BRYANT
INDUSTRIAL - 918-546-1313) price
1) Gunnite $7,000
2) Hand Tamped $ 5500

Firoze H. Gaslightwala
X2417

AFCO

INTERNATIONAL TECHNOLOGY CORPORATION

RECORD OF ☒ TELECON ☐ MEETING

Project Name	Number	Phase	Task	Subtas
US ACE CBC PROJECT	322243	002	03	005

Date 9/13/94

Time 11:15am

CALL FROM ☒ CALL TO ☐ NAME: F-H Gaslightail

CALL FROM ☒ CALL TO ☐ NAME: BRIAN BRUNER

Telephone Number: 502-776-1505

Company Name: FISHER KLOSTERMAN

Address: LOUISVILLE - KY

City

State

Zip Code

Other Participants — Name/Location/Representing:

NONE

Topic

PRICING

Summary (Decisions & Specific Actions Required by Named Persons):

F-2002 - CYCLONE SEPARATOR

MODEL XCO-U65-21 - w/6" REFRACTORY

$15,745= each

equired Action:

Prepared by (Signature): F11202e

stribution:
iginal to Project File
py to Project Manager
py to Preparer

☐ Other Distribution (By Preparer)

PAGE 1 OF 1

548A-8-8

INTERNATIONAL TECHNOLOGY CORPORATION

RECORD OF ☒ TELECON ☐ MEETING

Project Name	Number	Phase	Task	Subtask
US ACE CBC PROJECT	322243	002	03	005

Date 9/13/94	Time 11.15am	CALL FROM ☒ CALL TO ☐ NAME:	F-H Gaslightwala
Other Participants — Name/Location/Representing: NONE		CALL FROM ☒ CALL TO ☐ NAME:	DAN BANKS
		Telephone Number:	918-234-1800
		Company Name:	John Zink
		Address:	TULSA-OK.
		City	
Topic PRICING		State	Zip Code

Summary (Decisions & Specific Actions Required by Named Persons):

G-2001 - 5.00 M BTU/HR - VORTEX TYPE BURNER - NATURAL GAS-AIR W/ SPARK IGNITER

\# 25,000 each

Required Action:

Prepared by (Signature): F.Hoze

Distribution:
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PAGE 1 OF 1

548A-8-E

LECORP®

MANUFACTURERS' REPRESENTATIVES
MATERIAL HANDLING SYSTEMS SUPPLIERS

CORPORATE OFFICE: P.O. BOX 7508, PADUCAH, KY 42002
3503 CLINTON ROAD
502-554-9653
FAX: 502-554-9657

SALES OFFICES:

P.O. BOX 1954
BRENTWOOD, TN 37027
615-377-3719

812 LYNDON LANE
SUITE 7
LOUISVILLE, KY 40222
502-426-4141
FAX # 502-426-8348

SOUTHLAND BLDG
244 PETERS ROAD, NORTH
SUITE #207-208
KNOXVILLE, TN 37923
615-694-6150
FAX # 615-693-5931

P.O. BOX 381285
MEMPHIS, TN 38183
901-754-4800
FAX # 901-754-4573

FAX LETTER

TO: Firoze
COMPANY: IT Corp
CITY: Knoxville, TN
FAX NO. 615-690-3626 PAGES: 1

FROM: Charles W. Reeves
DATE: 9/14/94
SUBJECT: COOLING SCREW CONV.

ESTIMATE COOLING SCREW CONVEYOR,
HOLLOW FLIGHT 8"ϕ X 14' OAL.
\$50,000

H 1001

CC - MIKE CLARK

INTERNATIONAL TECHNOLOGY CORPORATION

RECORD OF ☒ TELECON ☐ MEETING

Project Name	Number	Phase	Task	Subtask
US ACE CBC PROJECT	322243	002	03	005

Date 9/13/94	Time 11.15am
CALL FROM ☒ CALL TO ☐ NAME:	F-H Gaslightail
CALL FROM ☒ CALL TO ☐ NAME:	FRANK KRETCCH
Telephone Number:	1-800-882-2877
Company Name:	SONIC
Address:	NEW YORK
City	
State	Zip Code

Other Participants — Name/Location/Representing:

NONE

Topic

PRICING

Summary (Decisions & Specific Actions Required by Named Persons):

T-5001- PARTIAL QUENCH. 5000 ACFM
INLET @ 1600°F - 400°F
OUTLET - 3 SECONDS RETENTION TIME
CARBON STEEL CONSTRUCTION
$30,000 each

Required Action:

Prepared by (Signature): FMcGee

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PAGE 1 OF 1

548A-6-8

INTERNATIONAL TECHNOLOGY CORPORATION

RECORD OF ☒ TELECON ☐ MEETING

Project Name	Number	Phase	Task	Subtask
US ACE CBC PROJECT	322243	002	03	005

Date 9/13/94 Time 11.15am

CALL FROM ☒ CALL TO ☐ NAME: F-H Gaslightinh

CALL FROM ☒ CALL TO ☐ NAME: MR Charles Reeves

Telephone Number: 502-554-9653

Company Name: LECORP

Address: ~~[illegible]~~ PADUCAH, KY

City

State

Zip Code

Other Participants — Name/Location/Representing: NONE

Topic: PRICING

Summary (Decisions & Specific Actions Required by Named Persons):

* H-5001- ROTARY AIRLOCK VALVE
2 CUFT/HR - 1000°F. FOR SOLIDS
$

H- 5002 - ROTARY AIRLOCK, VALVE
2cu/hr - 500°F. FOR SOLIDS
$ 6,000 — Carbonsteel

* ROTARY AIRLOCK VALVE NOT SUITable
because of ~~[illegible]~~
Temperature. Reqmts (max 700°F)
DOUBLE DUMPVALVE IS MORE SUITABLE
FOR THIS DUTY.
$7,000 each.

(It has 2 chambers- DRIVEN Flap in it
Pneumatic or Electric or gravity
operator)

Required Action:

Prepared by (Signature): F[illegible]

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PAGE 1 OF 1

548A-8-8

TOTAL P.01

SENT BY: I.T. CORP. KNOXVILLE ; 9-14-94 ; 4:33PM ; I.T. CORP KNOXVILLE→ 615 524 1100:# 1/ 2

Refax

TO

INTERNATIONAL TECHNOLOGY CORPORATION

IT CORPORATION
312 DIRECTORS DRIVE
KNOXVILLE, TN 37923
(615) 690-3211

TELECOPY REQUEST

TELECOPY NUMBER: 525-2305

TO: From (524-1100) MR George Bishop

Attn FROM: FIROZE FIROZE

DATE: 9/15 9/14/94 TIME: 4.30pm

NUMBER OF PAGES: 1 ~~2~~ (INCLUDING COVER SHEET)

REMARKS: Dear Mr Bishop,

Greetings

Please give Budget # to me on this baghouse. Thks

#130,000
BUDGET

OVERALL HEIGHT = 26' (INCLUDES HOPPER + CLEARANCE UNDER HOPPER)
WIDTH = 12'6"
LENGTH = 17'

DISCARD WHEN SENT ________

PLEASE RETURN ________

IF ALL PAGES ARE NOT RECEIVED, PLEASE ASK FOR EXTENSION 2223 AT THE ABOVE NUMBER. THANK YOU.

IT KNOXVILLE FAX NO. (615) 690-3626 OR
(615) 690-4652

6903626 P.01

SUSCON STACKS

Susquehanna Concrete Products, Inc.

410-676-3600 410-679-4242

42 Fort Hoyle Road, Magnolia Maryland 21101

FAX 410-676-7163

Z5001

DATE: 9/13/94

TO: IT Corp.

 # OF PAGES: 1

ATTN: FIRONE

SENDER: M. AFFLECK

FAX #: (615) 690-3626

FROM FAX #: 410-676-7163

MESSAGE: Per your telephoned request 12:00 p.m. today!

Budget Price ... $25,000.00 (FOB Magnolia Md.)

— (1) 18" I.D. x 50'-0" Freestanding Stack

— SC-1 Refractory (1800°F to 2,000°F)

— A-36 Steel painted.

— Includes: (1) tee, (1) clean-out, (1) 360° platform, (30') ladder w/ safety pole.

If there is a problem with this transmission, please call 410-676-3600

INTERNATIONAL TECHNOLOGY CORPORATION

RECORD OF ☒ TELECON ☐ MEETING

Project Name	Number	Phase	Task	Subtask
USACE	322243	002	03	005

Date: 9/28/94 Time: 11:15 am

CALL FROM ☒ CALL TO ☐ NAME: F H Gaslightwala

CALL FROM ☐ CALL TO ☒ NAME: CARL.

Telephone Number: 922-9038

Company Name: Ridenour Const

Address: Knoxville

City

State Zip Code

Other Participants — Name/Location/Representing:

Topic: PRICING (Optional)

Summary (Decisions & Specific Actions Required by Named Persons):

BUTLER Bldg – 120' long x 50' wide x 50' High.
w/ Gable Roof, & no slab
one 20' x 20' motorized EQUIPment DOOR
one Personnel Door
one – one TON window unit FOR HVAC.
4 – 3' x 3' windows
(no lighting) or other electrical

$17/SQFT
120 x 50 = 6000 x 17 = $102,000

Required Action:

Prepared by (Signature): FIRoze (x21159)

Distribution:
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PAGE 1 OF 1

548A-8-8

INTERNATIONAL TECHNOLOGY CORPORATION

RECORD OF ☒ TELECON ☐ MEETING

Project Name	Number	Phase	Task	Subtask
USACE	322243	002	05	005

ate 9/28/94 | Time 11.00 am

CALL FROM ☒ CALL TO ☐ NAME: F H Gaslightwala

CALL FROM ☐ CALL TO ☒ NAME: Mel Sparkman

Telephone Number: 205-916-0000

Company Name: Birmingham Hoist

Address: Birmingham, Ala

City

State | Zip Code

ther Participants — Name/Location/Representing:

opic

PRice

ummary (Decisions & Specific Actions Required by Named Persons):

HOIST 5 TON - 3 WAY.

56' x 25' x 48'

MOTORIZED

$ 30,000

equired Action:

Prepared by (Signature): x2454

FHG (FIROZE)

stribution:
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py to Preparer

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PAGE 1 OF 1

548A-8-87

INTERNATIONAL TECHNOLOGY CORPORATION

RECORD OF

☒ TELECON

☐ MEETING

Project Name	Number	Phase	Task	Subtask
USACE/CBC-	322243	02	03	005

Date 9/26/94 Time 4.00pm

CALL FROM ☐ CALL TO ☐ NAME: F H Gaslightwala

CALL FROM ☐ CALL TO ☒ NAME: Mr. Reeves

Telephone Number: 502-554-9653

Company Name: LeCORP

Address: Paducah

City Ky

State

Zip Code

Other Participants — Name/Location/Representing:

none.

Topic

Pricing

Summary (Decisions & Specific Actions Required by Named Persons):

H-2007 {
H-2008 } Bag Breaker $3,500= each

{ Integral Dust Pickup
MANUAL SHAKER
DROP IT ON KNIFE }

Required Action:

Prepared by (Signature):

FHG

Distribution:
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Copy to Project Manager
Copy to Preparer

☐ Other Distribution (By Preparer)

PAGE 1 OF 1

548A-6-8

INTERNATIONAL TECHNOLOGY CORPORATION

RECORD OF ☒ TELECON ☐ MEETING

Project Name	Number	Phase	Task	Subtask
US ACE CBC PROJECT	322243	002	03	005

Date: 9/26/94 Time: 11.15am

CALL FROM ☒ CALL TO ☐ NAME: F-H Gaslightwik

CALL FROM ☒ CALL TO ☐ NAME: MR DOUG

Telephone Number: 546-4921

Company Name: SPATCO

Address: Knoxville

City: Tn

State:

Zip Code:

Other Participants — Name/Location/Representing:

NONE

Topic: PRICING

Summary (Decisions & Specific Actions Required by Named Persons):

P 2001- PUMP- 10 GPM- 5' Head
1/10 HP → cooling water CENTRIFUGAL TYPE
$ 225=

Required Action:

Prepared by (Signature): FMcze

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PAGE 1 OF 1

548A-6-8

INTERNATIONAL TECHNOLOGY CORPORATION

RECORD OF ☒ TELECON ☐ MEETING

Project Name	Number	Phase	Task	Subtask
US ACE CBC PROJECT	322243	002	03	005

Date 9/26/94	Time 11:15am
CALL FROM ☒ CALL TO ☐ NAME:	F-H Gaslightwala
CALL FROM ☒ CALL TO ☐ NAME:	MR Alex Saliba
Telephone Number:	502-554-9653
Company Name:	Le Corp
Address:	Paducah
City	Ky
State	Zip Code

Other Participants — Name/Location/Representing:

NONE

Topic

PRICING

Summary (Decisions & Specific Actions Required by Named Persons):

H-2005 & H-2006 } Screw conveyors - 150#/HR variable speed DRIVE
one FOR aluminum oxide - (1/32")
one FOR Limestone - (chunks)
8' length assumed - carbon steel const.
$ 12,500 each

H-2002 & H-2004 } Hopper conical 3'x3' mount on TOP OF conveyor
$ 1,200 each

Required Action:

Prepared by (Signature): FHGaze

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PAGE 1 OF 1

548A-6-8

INTERNATIONAL TECHNOLOGY CORPORATION

(1)

By WMS Date 9/12/94 Subject EQUIP LIST Sheet No.___ of ___
Chkd. By___ Date___ USACE - CBC PROJECT Proj. No. ___

(1) B-2001 - COMB. AIR BLOWER - 6000 SCFM @ 30" W.C., AIR @ AMB. CARBON STEEL, ? HP

(2) B-2002 - LOOP-SEAL PURGE AIR BLOWER - 200 SCFM @ 30" W.C., AIR @ AMB. TEMP., CARBON STEEL, ? HP

(3) B-5001 - I.D. FAN - 6000 ACFM @ 60" W.C. VACUUM, CARBON STEEL, MAX TEMP = 450°F

(4) F-2001 - CBC - CARBON STEEL w/ 6" CASTABLE REFRACTORY, (SEE ATTACHED SKETCH)

(5) F-2002 - CYCLONE SEPARATOR - FISHER-KLOSTERMAN - SIZE 21, MODEL XQ-465, 6" OF CASTABLE REFRACTORY (502) 776-1505

(6) G-2001 - START-UP BURNER - NATURAL GAS-AIR BURNER, 5.0 MMBtu/hr CAPACITY w/ SPARK IGNITER

(7) T-5001 - PARTIAL QUENCH - 5000 ACFM INLET @ 1600°F, 400°F OUTLET TEMP., CARBON STEEL, (SONIC ENVIRONMENTAL SYSTEMS - 800-882-2877)

(8) H-5001 - ROTARY AIRLOCK - CARBON STEEL, 2 ft^3/hr CAPACITY, 1000°F TEMP. SOLIDS

(9) S-5001 - BAGHOUSE - (Attached)

(10) H-5002 - ROTARY AIRLOCK CARBON STEEL, 2 ft^3/hr CAPACITY, 500°F TEMP SOLIDS

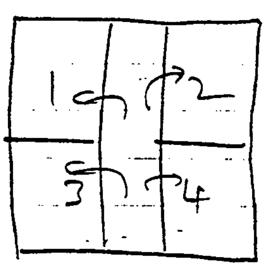
(11) Z-5001 - STACK - 50' TALL, 16" ϕ, CARBON STEEL

PROJECT = USACE - CBC PROJECT
322243.002.03.005

108-10-85

BAGHOUSE

- Flow - 3200 ACFM
- Air/cloth ratio: 3:1
- 4 modules (on-line cleaning) $\frac{3200}{4} =$
- 1067 ft2 filtering area
- 450°F
- Fiberglass bags
- max draft = -60" wc
- carbon steel construction
- Hopper heaters vibrators needed



inlet

INTERNATIONAL TECHNOLOGY CORPORATION

By SLM Date 9/25/94 Subject EQUIP SPECS Sheet No. ___ of ___

Chkd. By PR Date ___ New Additions. Proj. No. ___

2 Screw conveyors

H-2005 1- Feed Al_2O_3 particles (about 1/32")
Variable speed drive $25k each
150 lb/hr capacity
Carbon steel

H-2003 : 2- Feed lime stone granules
Variable speed drive $25k
150 lb/hr capacity

2 Hoppers (3'x3') Conical
1- limestone hopper (H-2002)
1- Aluminum oxide hopper (H-2004)
2- Bag breakers (H-2007, H-2008)

1 Hoist

H-2006 5 ton capacity
38 feet of steel cable
Horizontal rail mounted
Motorized for horizontal & vertical movement

1-PUMP P-2001 10 gpm, cooling water pump (centrifugal pump)

IT McGill
Pollution Control Systems

312 Directors Drive
Knoxville, Tennessee 37923
Telephone: 615-690-3211
FAX: 615-690-3626

RECORD OF ☒ TELECON ☐ MEETING

Project Name	Number	Phase	Task	Subtask
USAEC	32243			

8/25/94 | Time

CALL FROM ☐ CALL TO ☒ NAME: Steve Will

CALL FROM ☒ CALL TO ☐ NAME: P. Acharya

Telephone Number: 303-279-4501

Company Name: Hazen Research

Address:

City: Denver

State: Co

Zip Code:

r Participants – Name/Location/Representing:

P. Acharya
S. Will.

CBC pilot-plant configuration at Hazen Research.

mary (Decisions & Specific Actions Required by Named Persons):

Steve Will told me that Hazen has an operational CBC pilot plant consisting of a 6" ID x 24' tall, externally heated CCC, hot cyclone, water-cooled HE, Baghouse, venturi scrubber, ID fan and a stack.

The reactor shell is made of SS 309. The windbox and the jacketed hot gas chimney is made of refractory-lined carbon steel. The unit has a loop-seal between the cyclone and the combustor, similar to Ogden design.

The unit was originally designed for coal combustion, presently used to burn solids, sludges and liq HCs.

The CBC can operate at 1800°F. Feed rate = 4 to 8 gph red water

uired Action:

Prepared by (Signature): P. Acharya

ibution:
nal to Project File
to Project Manager
to Preparer

☐ Other Distribution (By Preparer)
P. O'Stergaard
C. Stolte
S. McNair

PAGE 1 OF 1

IT McGill
Pollution Control Systems

312 Directors Drive
Knoxville, Tennessee 37923
Telephone: 615-690-3211
FAX: 615-690-3626

RECORD OF ☒ TELECON ☐ MEETING

Project Name	Number	Phase	Task	Subtask
32242				

Time

CALL FROM ☐ CALL TO ☒ NAME: Mike Weimeke

CALL FROM ☒ CALL TO ☐ NAME: P. ACHARYA

Telephone Number: 414-798-6313

Company Name: Boliden-Allis

Address:

City

State

Zip Code

Participants – Name/Location/Representing:

M. Weimecke
P. Acharya

Pilot Plant configuration of Boliden Allis to burn red water

...ary (Decisions & Specific Actions Required by Named Persons):

Mike Weimeke told me ~~that~~ the pilot plant consists of a fluidized bed reactor, hot cyclone, partial quench, baghouse, ID fan and a stack.

The existing fluidized bed reactor (15" ID x 20') tall can be configured as a CBC by making necessary changes in the plant.

The red water feed rate to the reactor = 1.3 gpm at 1600°F operating temperature

...red Action:

Prepared by (Signature): P. Acharya

...tion:
...l to Project File
... Manager

☐ Other Distribution (By Preparer)
P. Olsdergard
G. Stolte
J. McNew

PAGE 1 OF 1

14.0 RECOMMENDED TESTS AND ANALYSES

14.0 Recommended Tests and Analyses

This chapter identified tests and analyses recommended for the pilot plant test.

14.1 Circulating Bed Combustor Unit

The following tests should be conducted in the CBC unit to optimize, select, and evaluate various parameters.

- ***Optimize the Bed Depth.*** The bed depth should be varied from 4 to 8 feet in the unit and the differential pressure (DP) across the CBC measured at each bed depth. The bed depth should then be optimized based on the CBC performance (e.g., destruction/removal efficiency [DRE], thermal efficiency) and the differential pressure across the CBC.

- ***Select the Appropriate Bed Material.*** Several bed materials were evaluated in Chapter 3.0 primarily from the agglomeration and heat transfer point of view. Different materials of different particle size distribution (PSD) should be tested in the CBC unit for agglomeration potential and heat transfer. Based on these tests, the final bed material and its PSD selection should be made.

- ***Evaluate the Use of Limestone as a Neutralizing Media.*** SO_x generation for the red water combustion at 1600°F has been estimated in Chapter 3.0. However, the SO_x generation rate should be measured at full load, and the effectiveness of limestone to neutralize SO_x (and, if necessary HCl) should be evaluated. If limestone performs inadequately, lime slurry injection at the partial quench should be considered and evaluated.

- ***Evaluate Impact of Steam in Circulating Bed.*** At a peak red water feed rate of 1.5 gpm, large quantities of steam will be generated. The steam will travel upwards with the circulating media through the cyclone and then to the APCS. The impact of steam on the circulating media should be assessed, with special attention to particle stickiness and agglomeration.

- ***Evaluate System Turn Down Capability.*** The ability of the system to operate at a steady state should be evaluated at different red water feed rates.

- ***Evaluate System Performance.*** At maximum red water feed rate, the stack gases should be sampled and analyzed to determine the DRE of the nitrobodies;

particulate HCl, SO_x, and NO_x emissions; and the emission rates of the ten Resource Conservation and Recovery Act (RCRA) metals. In addition, the cooled ash should be analyzed for nitrobodies, salts, and the ten RCRA metals.

- ***Finalize Start-Up Burner Location.*** Currently, a Vortex-type start-up burner is located at the bottom of the CBC to preheat the combustion air entering the bed. However, if any problems arise due to the location of the burner, the burner can be located above the bed. The burner location should be finalized during the tests based on the burner performance at the proposed location.

- ***Determine the Optimum Gas Velocity in the CBC.*** The gas velocity in the CBC is key for proper recirculation of the bed material and optimum performance of the cyclone. The CBC should be operated at different velocities (10 to 25 feet/sec), and the CBC/cyclone performance (e.g., carryover and particulate separation) evaluated. Based on these results, the optimum gas velocity for the CBC unit can be determined.

14.2 Hot Cyclone Unit. This section discusses issues relating to cyclone/loop-seal performance.

- ***Evaluate Cyclone/Loop-Seal Performance:***

  - The particulate slip from the cyclone should be measured at various inlet gas velocities (30 to 60 feet/sec) and DPs to determine the optimum DP across the cyclone; the objective is to minimize particulate slip.

  - The loop-seal should be operated at various loop-seal purge air flow rates to determine the optimum purge rate for the reliable and efficient transfer of bed material back to the CBC.

  - Percentage of theoretical NO_x emissions formed is determined at peak red water feed rate. Also, the stack gases are observed for the reddish-brown visual emissions of high concentration of NO_x.

  - If the uncontrolled NO_x emissions are unacceptable, and depending on the magnitude of the emissions and the required removal efficiencies, a deNO_x system should be tested. Based on the NO_x emission requirements, a thermal deNO_x system may be adequate. Such a system can be retrofitted at the duct exiting the hot cyclone. NO_x removal efficiency using the thermal deNO_x system should be determined at the peak red water feed rate.

14.3 Air Pollution Control System

The APCS consists of a partial quench, baghouse, I.D. fan, stack, and CEM system. The mechanical and process performance of each piece of the equipment at peak and turn down conditions should be determined.

- ***Determine the Optimum Air/Cloth Ratio in the Baghouse.*** The system is designed for an air-to-cloth ratio of 3:1 at full load conditions. The baghouse performance for particulate removal should be determined at various air-to-cloth ratios ranging from 1 to 3.

- ***Precoating of Bags with Lime.*** The baghouse is sized and designed to remove friable particulates and fine salt particles because the salts can be sticky, especially in the presence of high moisture in the flue gas. An evaluation should be made whether a lime precoat on the bags will improve the operational reliability.

15.0 OPERATIONS AND SAFETY CONSIDERATIONS

15.0 Operations and Safety Considerations

15.1 Introduction

The protection of workers and environmental health and safety (H&S) are major concerns during project implementation and cannot be compromised. This document presents a description of special H&S precautions related to operating and sampling a CBC for the destruction of red water for USAEC. This document is not intended to serve as the site health and safety plan (HASP).

15.2 Regulations and Guidelines

All activities conducted during the incineration of red water must be in compliance with applicable requirements of the following publications:

- 29 Code of Federal Regulations (CFR) 1926, Construction Industry, Occupational Safety and Health Administration (OSHA) Safety and Health Standards
- 29 CFR 1910, General Industry OSHA Safety and Health Standards
- 29 CFR 1910.120, OSHA Final Rule dated March 6, 1989, "Hazardous Waste Operations and Emergency Response"
- National Institute of Occupational Safety and Health (NIOSH)/OSHA/USCG/U.S Environmental Protection Agency (EPA), "Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities," October 1985
- American Conference of Governmental Industrial Hygienists (ACGIH), "Threshold Limit Values and Biological Exposure Indices," 1989-1990, or most current version
- U.S. Department of Health and Human Services (DHHS), "NIOSH Sampling and Analytical Methods," DHHS (NIOSH) Publication 84-100
- American National Standards Institute (ANSI), Practice for Respiratory Protection, Z88.2, 1980
- ANSI, Emergency Eyewash and Shower Equipment, Z41.1, 1983
- ANSI, Protective Footwear, Z358.1, 1981

- ANSI Physical Qualifications for Respirator Use, Z88.6, 1984
- ANSI, Practice for Occupational and Educational Eye and Face Protection, Z87.1, 1968.

15.3 Hazard Assessment

This section discusses the hazards that are anticipated to be encountered during operation of the CBC to burn red water. The potential hazards associated with operation of the CBC include chemical and physical hazards.

15.3.1 Chemical Hazards

Potential exists for personnel to come into contact with the following types of materials:

- Reactive and toxic feed materials
- Flammable solvents used in the sampling trains
- Toxic and corrosive combustion products.

15.3.1.1 Feed Materials

The feed materials during routine operations is red water. Red water is the aqueous effluent generated during sellite purification of crude TNT. The characteristics of red water are presented at the end of this chapter.

Explosion Potential. The red water has a solids heat content of 3,200 Btu/lb. The solids are in a solution that is 85 percent water, which makes the red water endothermic.

CBCs were originally designed to manage materials with high heat content for energy production. The level of energy in the red water will not be dangerous for the CBC. Additionally, the large internal volume of the CBC will dissipate any pressure shocks that could occur from uneven combustion of the red water.

Contaminated Surfaces. The red water will be pumped directly to the CBC feed port. In the unlikely event that red water is spilled, it should be cleaned up using wet methods and not allowed to dry. Dry TNT or related materials can explode due to friction or spark.

15.3.1.2 Ash

The ash from the CBC will be a fine particulate that may be toxic. It is unlikely that explosive materials will be found in the ash to present a physical or chemical hazard. Toxicity of the ash will be due to the presence of metals. The fine particulate will be a respiratory hazard.

Respiratory Protection. The following rules will be adhered to by all site personnel when respiratory protection is in use:

- Only properly cleaned, maintained, NIOSH/Mine Safety and Health Administration (MSHA)-approved respirators will be used on site.
- Selection of respirators, as well as any decisions regarding upgrading or downgrading of respiratory protection, will be made by the site H&S officer upon consultation with a senior health and safety professional.
- Used air-purifying cartridges will be replaced at the end of each shift or when load-up or breakthrough occurs.
- Only employees who have had pre-issued qualitative fit tests and annual fit tests thereafter will be allowed to work in atmospheres where respirators are required.
- If an employee has demonstrated difficulty in breathing during the fit test or during use, he/she will be given a physical examination to determine whether a respirator can be worn while performing the required duty.
- No employee will be assigned tasks requiring the use of respirators, if based upon the most recent examination, a physician determines that the employee will be unable to function normally wearing a respirator or that the health of the employee will be impaired by use of a respirator.
- Contact lenses are not to be worn while using any type of respiratory protection.
- Excessive facial hair (beards) prohibits proper face fit and effectiveness of respirators; therefore, persons required to wear full-face or half-face respirators must not have beards, wide mustaches, goatees, extended sideburns, or Fu Manchu mustaches. All personnel wearing full-face or half-face respirators will be required to be clean shaven prior to each day's shift.

- Each respirator will be individually assigned and not interchanged among employees without cleaning and sanitizing.
- Regular eyeglasses cannot be worn with full-face respirators because they interfere with the face-piece seal. Inserts must be utilized.
- The respiratory protection used on site will be in compliance with OSHA, 29 CFR 1910.134.

15.3.1.3 Sampling Trains

During testing programs, flammable solvents may be used in the sampling trains. Material Safety Data Sheets (MSDS) will be provided by the test team for these substances.

15.3.1.4 Spiking Materials

During testing programs, the feed stream may be spiked with materials that are toxic, reactive, flammable, and/or corrosive. It will be incumbent upon the test team to properly store and handle the spiking materials, and to provide MSDSs for these materials.

15.3.2 Physical Hazards

Several physical hazards are expected to be encountered during field activities. These hazards are similar to those associated with any mechanical project. These hazards include those due to poor housekeeping, equipment operation, the use of hand and power tools, handling and storage of fuels, and use of electrical power.

15.3.2.1 Noise

Noise is a potential hazard associated with the operation of mechanical equipment including the fans, blowers, power tools, pumps, and generators.

All on-site personnel will wear hearing protection in areas where noise levels exceed a time-weighted average (TWA) of 85 decibels (dBA). Hearing protection will be worn during activities if levels are suspected or shown to exceed 85 dBA. The site H&S officer will continuously identify areas with high noise levels. High noise areas will initially be monitored with a sound level meter or dosimeter. Areas with consistently high noise levels will have

signs posted notifying personnel that hearing protection is required. All employees working on or near the CBC will receive annual hearing conservation refresher training.

15.3.2.2 Heat Stress

Heat stress is a significant potential hazard associated with the use of protective equipment in hot weather environments. The signs and symptoms of heat stress and the physiological monitoring requirements are discussed below.

Heat Stress Monitoring. Heat stress is caused by a number of interacting factors, including environmental conditions, clothing, workload, and individual characteristics. Extreme hot weather can cause physical discomfort, loss of efficiency, or personal injury.

Individuals vary in their susceptibility to heat stress. Factors that may predispose individuals to heat stress include:

- Lack of physical fitness
- Insufficient acclimation
- Age
- Dehydration
- Obesity
- Alcohol and/or drug use
- Medical conditions
- Infection
- Sunburn
- Diarrhea
- Chronic disease.

Reduced work tolerance and the increased risk of heat stress are directly influenced by the amount and type of personal protective equipment (PPE) worn. PPE adds weight and bulk, severely reduces the body's normal heat exchange mechanisms (evaporation, convection, and radiation), and increases energy expenditure.

Signs and Symptoms of Heat Stress. If normal body temperature fails to be maintained because of excessive heat, a number of physical reactions can occur ranging from mild to fatal. Heat-related problems include:

- ***Heat Rash.*** Caused by continuous exposure to heat and humidity and aggravated by chafing clothes. Heat rash decreases the body's ability to tolerate heat, as well as being a nuisance.

- ***Heat Cramps.*** Caused by profuse perspiration with inadequate fluid intake. Heat cramps cause painful muscle spasms and pain in the extremities and abdomen.

- ***Heat Exhaustion.*** Caused by increased stress on various organs to meet increased demand to cool the body. Heat exhaustion causes shallow breathing; pale, cool, moist skin; profuse sweating; and dizziness. Heat exhaustion can be alleviated by promptly moving the affected individual to a cool place to lie down and providing cool fluids to drink.

- ***Heat Stroke.*** The most severe form of heat stress. Heat stroke symptoms include hot, dry skin; no perspiration; nausea; dizziness; confusion; strong, rapid pulse; and coma. The body must be cooled immediately to prevent severe injury or death. Relief is possible only by emergency measures that quickly reduce body temperature to avoid irreparable damage to the body.

Heat Stress Prevention. One or more of the following practices will help reduce the probability of succumbing to heat stress:

- Provide plenty of liquids to replace the body fluids lost by perspiration. Fluid intake must be forced because, under conditions of heat stress, the normal thirst mechanism is not adequate to bring about a voluntary replacement of lost fluids.

- Provide cooling devices to aid natural body ventilation; however, these devices add weight and should be balanced against worker comfort.

- If possible, install mobile showers or hose-down facilities to reduce body temperature.

- If possible, provide cool protective clothing.

- If possible, conduct field operations in the early morning.

- Acclimate workers to heat conditions when field operations are conducted during hot weather.
- Train personnel to recognize the signs and symptoms of heat stress and its treatment.
- Rotate personnel to various job duties if possible.
- Provide shade or shelter to relieve personnel of exposure to the sun during rest periods.

Individuals succumbing to the symptoms of heat stress will notify the site H&S officer. Early detection and treatment of heat stress will prevent further serious illness or injury and lost work-time. Proper and effective heat stress treatment can prevent the onset of more serious heat stroke or exhaustion conditions. Individuals having progressed to heat exhaustion or heat stroke become more sensitive and predisposed to additional heat stress situations.

Physiological Monitoring. Ambient temperature and other environmental factors provide basic guidelines to implement work/rest periods. However, because individuals vary in their susceptibility to heat stress, physiological monitoring will be used to regulate each individual's response to heat stress when ambient temperatures exceed 70°F. Monitoring frequency will increase as ambient temperature increases. The three physiological parameters that each individual will monitor are:

- ***Heart Rate.*** Each individual will count his/her radial (wrist) pulse for 30 seconds as early as possible in the first rest period. If the heart rate of any individual on the sampling team exceeds 100 beats per minute at the beginning of the rest period, then the work cycle will be decreased by one-third. The rest period will remain the same.
- ***Oral Temperature.*** Each individual will measure his/her oral temperature with a single-use clinical thermometer for 1 minute as early as possible in the first rest period. If the oral temperature exceeds 98.6°F at the beginning of the rest period, then the work cycle will be decreased by one-third. The rest period will remain the same.
- ***Body Water Loss.*** Each individual will weigh his/her self before starting work and at the end of each work shift.

An individual is not permitted to return to work if his/her oral temperature exceeds 100.6°F.

Physiological monitoring information will be recorded on the Employee Record for Heat Stress. All monitoring will be performed by persons with a minimum of current Red Cross first-aid certification and individualized training to recognize the symptoms of heat stress. The site H&S officer will specify the work cycle period and the rest cycle period based on heat stress monitoring as per 1991-1992 ACGIH Threshold Limit Values (TLV).

15.3.2.3 Cold Stress

At certain times of the year, workers may be exposed to the hazards of working in cold environments. Potential hazards in cold environments include frostbite and hypothermia, as well as slippery working surfaces, brittle equipment, and poor judgement.

To minimize the risk of the hazards of working in cold environments, workers will be trained to recognize the physiologic responses of the body to cold stress.

Physiologic Response to Cold Stress. Personnel who are exposed to temperatures below -10°F with wind speeds of greater than 5 miles per hour (mph) will be medically certified as suitable for such exposure. Employees will be protected from exposure to cold so that their body core temperature does not fall below 98.6°F. Lower body temperatures result in reduced alertness and a reduction in thought processes or loss of consciousness.

Pain in the extremities (i.e, fingers, toes, ears, and nose) may be the first signs of cold stress, because these areas have high surface area-to-volume ratios. Uncontrollable shivering occurs during exposure to cold when the body core temperature falls below 95°F. This symptom should be taken as a sign of danger, and work terminated with workers moving to a warm environment.

Ambient air temperature and the velocity of the wind influence the development of a cold injury. Wind chill is used to describe the chilling effect of moving air in combination with low temperature. As a general rule, the greatest incremental increase in wind chill occurs when a 5-mph wind increases to 10 mph. Additionally, water conducts heat 240 times faster

than air. Thus, the body cools suddenly when chemical protective clothing is removed and clothing beneath is soaked with perspiration.

Signs and Symptoms of Cold Stress. Local injury resulting from cold is included in the generic term "frostbite;" however, there are several degrees of damage. Cold-related injuries include:

- Frost nip or incipient frostbite is characterized by sudden whitening or blanching of the skin.

- Superficial frostbite gives the skin a waxy appearance and is firm to the touch, but the tissue beneath is resilient. Superficial frostbite can be treated by covering the cheeks with warm hands, placing frostbitten fingers beneath the armpit next to the skin, or placing frostbitten feet beneath the clothing against the skin of a companion.

- Deep frostbite is characterized by cold, pale, and solid tissues. Deep frostbite is an extremely serious injury and affected individuals will seek medical attention.

- Systemic hypothermia is caused by exposure to freezing and rapidly dropping temperatures. Hypothermia symptoms are visually exhibited in five stages:

  - Shivering

  - Apathy, listlessness, sleepiness, and sometimes rapid cooling of the body to less than 95.5°F

  - Unconsciousness, glassy stare, slow pulse, and slow respiratory rate

  - Freezing of the extremities

  - Death.

Cold Stress Prevention. Prevention of frostbite is a function of whole-body protection:

- Adequate insulated clothing should be worn when the air temperature is below 40°F. Insulated coveralls, thermal socks, long underwear, hard hat liners, and other cold-weather gear aid in the prevention of hypothermia.

- Warm break areas and drinks (no caffeinated coffee) aid in warming the body.

- Train personnel to recognize the signs and symptoms of cold-related injuries and their treatment.

- Personnel will try to keep from getting their bodies and clothing wet, as this will only accelerate the effects of cold stress. However, if personnel should get wet, they will be allowed to dry off and change clothes.

- In addition, reduced work periods may be necessary in extreme conditions to allow rest in a warm area.

15.3.2.4 Burn Hazards

The surface of the CBC will be more than 300°F. Therefore, there is a real burn hazard. Other hot spots may be the ash, the baghouse, the fans, the stack, and all duct work. Burns can be prevented by avoiding contact with hot surfaces and by using the proper protective equipment when working on or near hot surfaces.

15.3.2.5 Explosion Hazard

The auxiliary fuel for the CBC will be natural gas. To prevent an explosive buildup of natural gas in the CBC the following will be observed:

- All auxiliary fuel valves will be installed in a double block and bleed manner

- CBC will be purged with air before the burner is started

- CBC temperature will be above 1300°F before auxiliary fuel is fed directly to the CBC

- Flame sensor will monitor the flame whenever a burner is in operation.

15.3.2.6 Fire Hazard

High temperature in the baghouse could cause the bags to catch fire. To prevent this problem, the temperature of the gases before the baghouse will be continuously monitored and if the temperature exceeds the manufacturer's recommended maximum temperature, the auxiliary fuel will be cut off.

15.3.2.7 Confined Space Entry

The CBC shall be evaluated to determine if any spaces are permit-required confined space. A permit-required confined space is a space that:

- Contains or has the potential to contain a hazardous atmosphere
- Contains a material that has a potential for engulfing an entrant
- Is configured such that an entrant could be trapped or asphyxiated
- Contains any other safety or health hazard.

A sign reading "DANGER--PERMIT-REQUIRED CONFINED SPACE, DO NOT ENTER" will be posted at the entrance to any confined space.

Before entry into a permit-required confined space, a permit must be obtained from the site H&S officer. Only properly trained, authorized entrants may enter a confined space. A properly trained attendant must monitor the entrant from outside of the confined space. The appropriate PPE must be worn by the entrant and available for the rescue service.

15.3.3 Activity Hazard Analysis

This section provides an analysis of the likelihood of exposure to chemical and physical hazards and the risks associated with those exposures.

15.3.3.1 CBC Erection

The likelihood of exposure to chemical hazards is low, and the associated risk is low.

The likelihood of exposure to physical hazards is low to moderate. Heavy equipment operation and working at elevated locations pose moderate hazards during CBC erection. Other anticipated physical hazards include noise, electrical hazards, pinch points, heavy lifting, fuel handling, and heat stress. Control measures that will be employed to reduce the potential risk of exposure include properly maintained heavy equipment, employee training to recognize physical hazards, and adherence to the heat and cold stress guidelines contained in the HASP.

15.3.3.2 Performance Testing

During the performance test, samples of the red water will be analyzed. The red water may be spiked with organic chemicals and heavy metals, which present potential inhalation and skin contact hazards during the addition and subsequent sample handling activities. Control measures that can be employed to significantly reduce the potential risk of exposure include enclosed mixing and the use of PPE.

The likelihood of exposure to physical hazards is low to moderate. Equipment operation and material handling activities pose low hazards during trial burn preparation activities. Other physical hazards include heavy lifting, noise, electrical hazards, fire, and elevated work areas. Control measures that will be used to reduce the potential risk of exposure include proper equipment maintenance, trained operators, grounding and bonding during liquid transfer, adherence to lock-out/tag-out procedures, and utilization of proper tie-off procedures.

15.3.3.3 Maintenance Operations

The likelihood of exposure to chemical hazards during maintenance activities is low. The area of concern for this analysis is from the feed port to the stack. All red water that enters the CBC will be combusted, so red water (and its constituents) will not be present in the CBC during maintenance operations. A separate analysis of maintenance of the waste feed system should be considered, but this is beyond the scope of this document.

The likelihood of exposure to physical hazards is low to moderate. The risk associated with exposure to these agents is moderate, based upon the potential for serious injury from electrical hazards, pinch points, and moving equipment. Control measures that will be employed to reduce the potential risk of exposure include employee training and the preparation of site-specific standard operating procedures (SOP). Examples of these procedures include:

- Lockout/tagout procedure
- Confined space industrial
- Welding, cutting, and other hot work in hazardous locations
- Isolation of and entry into the CBC.

15.3.3.4 Operation of the CBC

A variety of chemical and physical hazards are associated with the operation of the CBC. The primary control measures include good engineering design, employee training, and the preparation of site-specific SOPs.

The likelihood of exposure to chemical hazards during routine operations is low and should be limited to exposure during sampling of the waste feed and the ash.

The likelihood of exposure to physical hazards is low to moderate. Hazards addressed in the SOPs will include noise, electrical hazards, work at elevations, slip/trip hazards, pinch points, and hot surfaces.

Either a task-specific hazard analysis or an SOP will be developed prior to starting a particular task.

RISK ASSESSMENT OF MUNITIONS CHEMICALS IN DRINKING WATER

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OFFICE OF WATER

RISK ASSESSMENT OF MUNITIONS CHEMICALS TO DEVELOP DRINKING WATER HEALTH ADVISORIES

The US Army and the US Environmental Protection Agency established a Memorandum of Understanding to cooperate in developing Health Advisories (HA) for munitions chemicals that may occur in drinking water. Health Advisories, developed by the Office of Drinking Water, describe nonregulatory concentrations of drinking water contaminants at which adverse health effects are not expected to occur over specific exposure durations. They provide informal technical guidance that assist public health officials when contaminations occur. Health Advisories (HA) are developed for One-day, Ten-day, Longerterm (7 years or 10% lifetime) and Lifetime exposures based on systemic, noncarcinogenic toxicity. A threshold dose-response relationship is assumed. Lifetime HAs are not recommended for known or probable human carcinogens (EPA classes A and B, respectively). A potency value (unit risk), derived from the linearized multistage model with 95% upper confidence limits, is used to calculate risk for a lifetime exposure to carcinogens in drinking water.

Health Advisory Values

General formula used for 1-day (based on toxicity studies with 1 to 5 days exposure), 10-day (based on toxicity studies with 7 to 14 days exposure), or longer term (up to 7 years; based on toxicity studies with 90 days to 1 year exposure) advisory limits.

$$HA = \frac{(NOAEL\ or\ LOAEL)\ (BW)}{(UF)\ (L/day)} = mg/L$$

where:

NOAEL or LOAEL = No- or Lowest-Observed-Adverse-Effect Level in (mg/kg bw/day)

BW = assumed body weight of a child (10 kg) or an adult (70 kg)

UF = uncertainty factor (10, 100, 1000) in accordance with NAS/ODW guidelines

L/day = assumed water consumption of a child (1 L/day) or an adult (2 L/day)

Lifetime Health Advisory

Three-step process for calculating lifetime HA value:

Step 1: Determination of Reference Dose (RfD)
An estimation of daily human exposure likely to be without appreciable risk of deleterious (non-carcinogenic) health effects in the human population (including sensitive subgroups) over a lifetime.

Step 2: Determination of Drinking Water Equivalent Level (DWEL)

$$DWEL = \frac{(Rfd)(BW)}{(2\ L/day)}$$

where:	RfD	=	Reference Dose
	BW	=	assumed adult body weight (70 kg)
	2 L/day	=	assumed water consumption of adult

Step 3: Determination of Lifetime HA value

HA = (DWEL)(RSC) = mg/L

where:	DWEL	=	Drinking Water Equivalent Level
	RSC	=	Relative Source Contribution; assumed percentage of daily exposure contributed by ingesting drinking water.

Carcinogenic Risk Categories

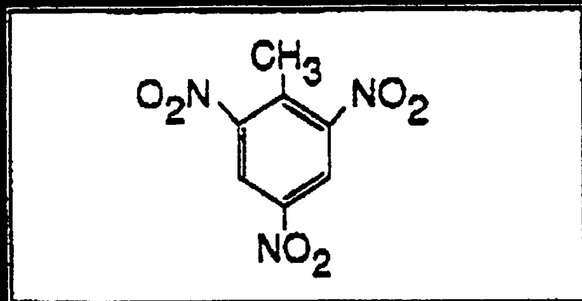
Drinking water contaminants are categorized according to their carcinogenic potential:

Group A Human Carcinogen
Group B Probable Human Carcinogen
Group C Possible Human Carcinogen
Group D Not Classifiable
Group E No Evidence of Carcinogenicity for Humans

Group A and B Carcinogens:
Upper-bound excess cancer risk estimated by the Linearized Multistage (LMS) mathematical model. The LMS model fits linear dose-response curves to low doses and is consistent with a no-threshold model of carcinogenesis.

Group C Contaminants:
Health risk based on a noncarcinogenic endpoint with an additional uncertainty factor (of from 2 to 10) applied to the Lifetime Health Advisory. The extra factor provides an additional safety margin to account for possible cancer effects.

2,4,6-Trinitrotoluene (TNT)



Health Advisory Values

One-Day (Child)	0.02 mg/L*
Ten-Day (Child)	0.02 mg/L*
Longer-Term (Child)	0.02 mg/L
Longer-Term (Adult)	0.02 mg/L
Lifetime	0.002 mg/L

Basis of Longer-Term (Child and Adult) and Lifetime HAs: Levine *et al.* (1983); Lowest-Observed-Adverse-Effect Level (0.5 mg/kg/day) for liver effect (hepatocytomegalia) in dogs exposed for 26 weeks via diet.

*No data available to develop short-term HA values. Value shown is an estimate based on longer-term HA for 10 kg child.

Genotoxicity

Salmonella: Positive
In vivo Bone Marrow (Rat): Negative
In vitro UDS Human Diploid Fibroblasts: Negative
Bone Marrow Micronucleus Assay: Negative
In vivo/In vitro UDS Hepatocytes (Rat): Negative

Two-Year Bioassays

Mice: Negative
Rats: Positive for urinary bladder papillomas and carcinomas in females

Potency: SF = 3×10^{-2} $(mg/kg/day)^{-1}$

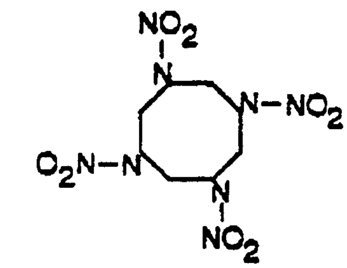
Cancer Model for 10^{-4} Risk

Linearized Multistage	1μg/L
One-Hit	0.7μg/L
Probit	700μg/L
Logit	20μg/L
Weibull	10μg/L

Cancer Classification

EPA Group C, Possible Human Carcinogen

Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)



Health Advisory Values

One-Day (Child)	5mg/L*
Ten-Day (Child)	5mg/L*
Longer-Term (Child)	5mg/L
Longer-Term (Adult)	20mg/L
Lifetime	0.4mg/L

Basis of Longer-Term (Child and Adult) and Lifetime HA: Everett *et al.* (1985); No-Observed-Adverse-Effect Level (50 mg/kg/day) for liver lesions in male rats fed HMX in the diet for 90 days.

*No data available to adequately develop short-term HA values. Value shown is an estimate based on longer-term HA for 10 kg child.

Genotoxicity*

Salmonella: Negative

Saccharomyces cerevisiae: Negative

*Results are inconclusive because of the low concentrations assayed or lack of data in the reports.

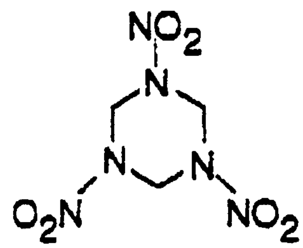
Two-Year Bioassays

No studies found in the literature

Cancer Classification

EPA Group D, Not Classifiable as to Human Carcinogenicity

Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)



Health Advisory Values

One-Day (Child)	0.1mg/L*
Ten-Day (Child)	0.1mg/L*
Longer-Term (Child)	0.1mg/L
Longer-Term (Adult)	0.4mg/L
Lifetime	0.002mg/L

Basis of Lifetime HA: Levine *et al.* (1983); No-Observed-Adverse-Effect Level (0.3 mg/kg/day) for prostate effects (suppurative inflammation) in rats exposed via diet for 24 months.

Basis of Longer-Term HA: Martin and Hart (1974); No-Observed-Adverse-Effect Level (1 mg/kg/day) for neurological effects (convulsions) in cynomolgus monkeys exposed via diet for 90 days.

*No data available to develop short-term HA values. Value shown is an estimate based on longer-term HA for 10 kg child.

Genotoxicity

Salmonella: Negative
Dominant Lethal (Rats): Negative
In vitro UDS Human Fibroblasts: Negative

Two-Year Bioassays

Rats (Two Strains): Negative
Mice: Positive for hepatocellular carcinomas and adenomas in females

Potency: SF $=1.1\times10^{-1}$ (mg/kg/day)$^{-1}$

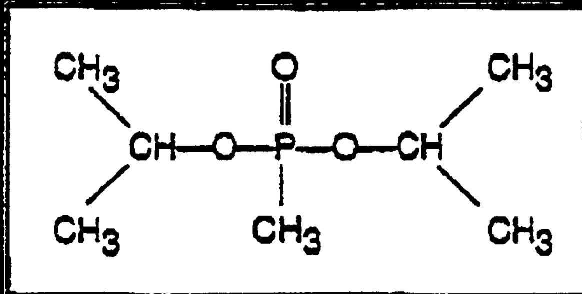
Cancer Model for 10^{-6} Risk

Linearized Multistage	0.3µg/L
Probit	<0.002µg/L
Logit	<0.002µg/L
Weibull	<0.002µg/L

Cancer Classification

EPA Group C, Possible Human Carcinogen

Diisopropyl methylphosphonate (DIMP)



Health Advisory Values

One-Day (Child)	8mg/L*
Ten-Day (Child)	8mg/L*
Longer-Term (Child)	8mg/L
Longer-Term (Adult)	30mg/L
Lifetime	0.6mg/L

Basis of Longer-Term (Child and Adult) and Lifetime HA: Hart (1980); Developed NOAEL of 75 mg/kg/day based on 90-day dietary study in dogs.

*No data available for developing short-term HA values. Value shown is an estimate based on longer-term HA for 10 kg child.

Genotoxicity

Salmonella: Negative

Saccharomyces cerevisiae: Negative

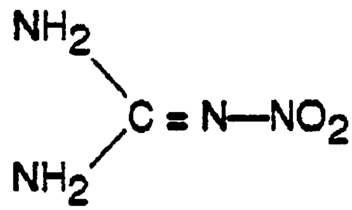
Two-Year Bioassays

No studies found in the literature

Cancer Classification

EPA Group D, Not Classifiable as to Human Carcinogenicity

Nitroguanidine



Health Advisory Values

One-Day (Child)	11mg/L*
Ten-Day (Child)	11mg/L
Longer-Term (Child)	11mg/L
Longer-Term (Adult)	37mg/L
Lifetime	0.74mg/L

Basis of Lifetime HA Value: Morgan *et al.* (1988b); Body and organ weight changes in female rats exposed for 90 days via diet.

Basis of Ten-Day HA Value: Morgan *et al.* (1988a); Increased water consumption, decreased electrolytes, and decreased heart weights in rats exposed for 14 days.

Basis of longer-term HA value: Morgan *et al.* (1988b); Decreased body weight, increased brain/body weight ratio, and increased water consumption in rats exposed for 90 days via diet.

*No data available to develop one-day HA value. Value shown is an estimate based on ten-day HA.

Genotoxicity

Salmonella: Negative
Mouse Lymphoma Cells: Negative
In vitro Chinese Hamster Ovary: Negative
Dominant Lethal (Rat, Mice): Negative

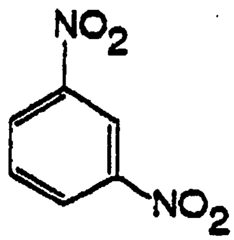
Two-Year Bioassays

No studies found in the literature

Cancer Classification

EPA Group D, Not Classifiable as to Human Carcinogenicity

1,3-Dinitrobenzene (DNB)



Health Advisory Values

One-Day (Child)	0.4 mg/L*
Ten-Day (Child)	0.4 mg/L*
Longer-Term (Child)	0.4 mg/L
Longer-Term (Adult)	0.14 mg/L
Lifetime	0.001 mg/L

Basis of Lifetime and Longer-Term (Child and Adult) HAs: Cody *et al.* (1981); No-Observed-Adverse-Effect Level (1.3 mg/kg/day) for effects on spleen (hemosiderin deposition) and testes (reduced weight and decreased spermatogenesis) in rats given 1,3-DNB in drinking water for 16 weeks.

*No data is available to develop one-day and ten-day HAs. Values shown are estimates based on the longer-term HA for a 10 kg child.

Genotoxicity

Salmonella: Mixed results (positve & negative in same strain)
Saccharomyces cerevisiae: Negative
Escherichia coli: Negative
In vitro UDS in rat hepatocytes: Negative

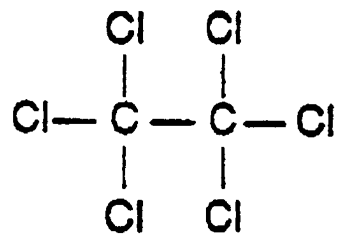
Two-Year Bioassays

No studies found in the literature

Cancer Classification

EPA Group D, Not Classifiable as to Human Carcinogenicity

Hexachloroethane



Health Advisory Values

One-Day (Child)	5 mg/L*
Ten-Day (Child)	5 mg/L
Longer-Term (Child)	0.1 mg/L
Longer-Term (Adult)	0.45 mg/L
Lifetime	0.001 mg/L

Basis of Lifetime and Longer-Term (Child and Adult) HAs: Gorzinski *et al.* (1980); No-Observed-Adverse-Efffect Level (1.3 mg/kg/day) for liver (hepatocytomeglia) and kidney (renal tubular atrophy and degeneration) lesions in rats fed hexachloroethane in the diet for 16 weeks.

Basis of Ten-Day HA: Gorzinski *et al.* (1980); No-Observed-Adverse-Effect Level (50 mg/kg/day) for liver hepatic necrosis and decrease in body weight gain in rats fed hexachloroethane in the diet for 16 days.

*No data available to develop one-day HA. Value shown is an estimate based on the ten-day HA.

Genotoxicity

Salmonella: Negative

Saccharomyces cerevisiae: Negative

Two-Year Bioassays

Rats: Positive for renal carcinomas and adenomas in males

Mice: Positive for hepatocellular carcinoma in males and females

Potency: SF = 1.4×10^{-2} $(mg/kg/day)^{-1}$

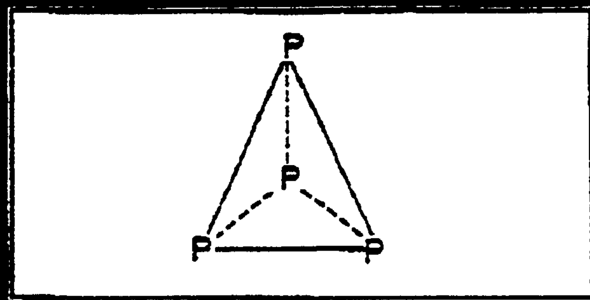
Cancer Model for 10^{-4} Risk

Linearized Multistage	3 µg/L
One-Hit	1 µg/L
Probit	5000 µg/L
Logit	50 µg/L
Weibull	2 µg/L

Cancer Classification

EPA Group C, Possible Human Carcinogen

White Phosphorus



Health Advisory Values

One-Day (Child)	Not recommended*
Ten-Day (Child)	Not recommended*
Longer-Term (Child)	Not recommended*
Longer-Term (Adult)	Not recommended*
Lifetime	0.0001 mg/L

Basis of Lifetime HA: Condray (1985); No-Observed-Adverse-Effect Level (0.015 mg/kg/day) for parturition mortality in female rats fed White Phosphorus in the diet for 4 to 6 months.

*Not recommended due to the extreme toxicity of White Phosphorus following oral ingestion.

Genotoxicity

Salmonella: Negative

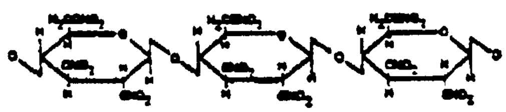
Two-Year Bioassays

No studies found in the literature

Cancer Classification

EPA Group D, Not Classifiable as to Human Carcinogenicity

Nitrocellulose



Health Advisory Values

Nitrocellulose was non-toxic at all doses studied, and failed to be digested and absorbed in all species (rats, dogs, and mice) tested.

Health Advisory values appear to be unnecessary.

Genotoxicity

Salmonella: Negative
In vivo Kidney Cells and Lymphocytes (Rat): Negative
In vivo Bone Marrow and Kidney Cell (Rat): Negative

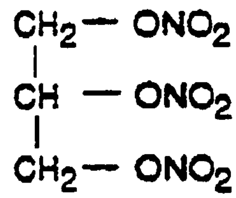
Two-Year Bioassays

Dogs: Negative
Rats: Negative
Mice: Negative

Cancer Classification

Not Classified by EPA

Trinitroglycerol (TNG)



Health Advisory Values

One-Day (Child)	0.005mg/L
Ten-Day (Child)	0.005mg/L
Longer-Term (Child)	0.005mg/L
Longer-Term (Adult)	0.005mg/L
Lifetime	0.005mg/L

Basis of HA values: Human No-Effect-Level for vasodilation. Animals were generally less sensitive to the effects of TNG.

Genotoxicity

Salmonella: Negative to Weak
In vivo Bone Marrow and Kidney Cell (Rat): Negative
Dominant Lethal (Rat): Negative
In vivo Kidney Cells and Lymphocytes (Dog, Rat): Negative
In vitro Chinese Hamster Ovary: Negative

Two-Year Bioassays

Dogs: Negative
Mice: Negative
Rats: Positive for hepatocellular carcinoma (males and females)

Potency: $SF = 1.66 \times 10^{-2}$ $(mg/kg/day)^{-1}$

Cancer Model for 10^{-6} Risk

Linearized Multistage	2µg/L
One-Hit	2µg/L
Probit	120µg/L
Logit	0.4µg/L
Weibull	0.1µg/L

Cancer Classification

Not Classified by EPA

AUG-31-1994 12:21

January 1989

TRINITROTOLUENE

Health Advisory

Office of Drinking Water
U.S. Environmental Protection Agency
Washington, DC 20460

II. GENERAL INFORMATION AND PROPERTIES

Trinitrotoluene (TNT) or, more specifically, α-TNT is the common designation for 2,4,6-trinitrotoluene, the most widely used military high-explosive (Castorina, 1980). For purposes of this HA, the synonym, TNT, will be used throughout to refer to 2,4,6-trinitrotoluene. Along with TNT, the symmetrical isomer, five meta or unsymmetrical trinitrotoluene isomers are found in the crude product resulting from the nitration of toluene with nitric acid in the presence of sulfuric acid. The nitration occurs in a step-wise fashion by a batch or continuous process.

The continuous process as employed at the Radford Army Ammunition Plant (RAAP), a prototype for Army Ammunition Plants (AAPs), utilizes 99% nitric acid and 44% oleum (109% sulfuric acid, a solution of sulfur trioxide in anhydrous sulfuric acid; Small and Rosenblatt, 1974) to nitrate toluene in six stages to crude TNT which is then subjected to purification with aqueous sodium sulfite (sellite) (Ryon et al., 1984). This process has been further modified to employ eight nitrator vessels fitted with dynamic (centrifugal) separators, thereby ensuring a greater degree of safety and efficiency. The purification process consists of two acid washes, three sellite washes and two post-sellite washes.

The crude TNT contains approximately 5% of the meta-isomers. These are reduced to about 0.6% by the sellite purification. Crude TNT also contains approximately 1% of the six dinitrotoluene (DNT) isomers, which are not removed during purification, and slightly more than 1% oxidation products, which are reduced to <1% by purification. Three additional impurities, amounting to <1%, are introduced by the sellite process (Ryon et al., 1984). Total impurities constitute not more than 3.24% of the finished TNT (Pal and Ryon, 1986).

The resulting monoclinic rhombohedric crystals, as described in Rosenblatt et al. (1971), when very pure, melt at 80.99°C, although a melting point as high as 81.6°C has been reported and 80.65°C is a commonly accepted figure (80.1 - 81.6°C). The color is usually pale yellow, but a chromatographically purified sample has been described as faintly yellow to pure white. A boiling point of 210° to 212°C at 10 to 12 mm Hg has been determined. The specific gravity has been variously reported over the range of 1.3 to 1.6 gm/cc. Although the solubility of TNT in water at 20°C is only 0.013% (130 mg/L), this is significant for pollution and health issues. Its solubility in organic solvents runs much higher, e.g., 109 gm/100 g of acetone at 20°C.

Two grades of TNT are used for military purposes and their purities are measured by the solidification point (also termed freezing point or setting point), which is considered more reproducible than a melting point. Grade III, the more highly purified grade, has a solidification point of 80.4°C, minimum, and exists as a fine crystalline form (Department of the Army, 1967).

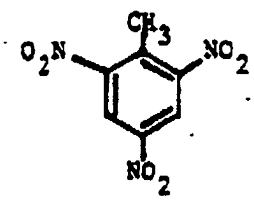
General chemical and physical characteristics of TNT are presented in Table II-1.

Trinitrotoluene is among the least impact- and friction-sensitive of the high explosives and the impurities formed during its production (except for tetranitromethane) do not affect its sensitivity. It can be further desensitized, however, by adding certain stabilizing substances in small quantity (1% to 2%) (Rosenblatt et al., 1971).

The chemical stability of TNT is such that, even at 150°C, it undergoes no great decomposition in 40 hours. Molten TNT can be stored at 85°C for 2 years without any decrease in purity. TNT has been found to withstand storage at magazine temperatures for 20 years without any measurable deterioration. Furthermore, moisture has no effect on the stability of TNT, which is unaffected by immersion in sea water (Department of the Army, 1967).

TABLE II-1

GENERAL CHEMICAL AND PHYSICAL PROPERTIES OF 2,4,6-TRINITROTOLUENE[a]

CAS Number	118-96-7
Names	TNT, α-trinitrotoluol, 1-methyl-2,4,6-trinitrobenzene, trotyl, tolite, triton, tritol, trilite, α-TNT
Molecular weight	227.13
Empirical formula	$C_7H_5N_3O_6$
Structure	
Color	Yellow to white
Physical state	Monoclinic rhombohedral crystals
Specific gravity	1.654
Liquid density	1.465 g/cm^3
Vapor pressure	0.053 mm (85°C); 0.106 mm (100°C)
Solubility characteristics	Water: 0.013 g/100 g (20°C) Carbon tetrachloride: 0.65 g/100 g (20°C) Toluene: 55 g/100 g (20°C) Acetone: 109 g/100 g (20°C)
Melting point	80.1 - 81.6°C
Boiling point	210°C (10 mm) - 212°C (12 mm)
Freezing point	80.75 ± 0.05°C
Flash point	240°C (explodes)
Conversion factor	1 ppm = 9.28 mg/m^3 (25°C; 760 mmHg) 1 mg/m^3 = 0.108 ppm (25°C; 760 mmHg)

a/ References: Clayton and Clayton (1981); Rosenblatt et al. (1973); Department of the Army (1967); Windholz (1976); Zakhari and Villaume (1978)

III. OCCURRENCE

Trinitrotoluene was produced and used on an enormous scale during World War I and World War II and may be considered the most important military bursting charge explosive. It has found wide application in shells, bombs, grenades, demolition explosives and propellant compositions (Department of the Army, 1967).

Trinitrotoluene is manufactured primarily by the continuous process, as described above, in Army Ammunition Plants (AAPs). Production from 1969-1971 was reported as 45 million pounds/month with a capacity of 85 million pounds/month (Ryon et al., 1984). It has been reported that as much as one half million gallons of wastewater have been generated per day by a single plant involved in the production of TNT (Hartley et al., 1981).

Trinitrotoluene wastes have a unique terminology as described in Rosenblatt et al. (1973). "Nitrobodies" include TNT, other TNT isomers, products from the sellite purification process and by-products from the production process. The spent sellite washings are high in solids content and are called "red water". Ryon et al. (1984) have reported that "TNT is the largest single non-polar component". The major organic components identified are 2,4-dinitrotoluene-3-sulfonate and 2,4-dinitrotoluene-5-sulfonate, which make up approximately one-third of the polar organic fraction. Such water is intensely red-colored and either is sold to paper mills for sulfur content or is concentrated by evaporation and incinerated. It is not amenable to purification and, because it is classified by EPA as a hazardous waste, it cannot be discharged into streams.

"Pink water" comes from both manufacturing plants and from load, assemble and pack (LAP) facilities. That from manufacturing plants can arise from Mahon fog filter affluents and nitrator fume scrubber discharges and is known to consist of the DNTs. While not positively identified, these two sources of "pink water" are also believed to contain all TNT isomers, mononitrotoluenes (MNTs) and possibly dinitro-m-cresols arising from the displacement of a nitro group on TNT isomers. Additionally, "pink water" from manufacturing plants arises from "red water" distillates (evaporator condensate from concentration process) and consists of DNTs, while those from finishing building hood scrubber and wash-down effluents are also believed to contain primarily DNTs. Spent acid recovery wastes may be an additional source of "pink water" generated during the manufacturing process (Dacre and Rosenblatt, 1974). On the other hand, "pink water" from LAP facilities, resulting primarily from shell washout operations, contains essentially pure TNT, usually contaminated with hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) or other additives. The pink color — pale straw to brick red — arises under neutral or basic conditions, especially when the wastes are exposed to sunlight (Rosenblatt et al., 1973).

A number of photodegradation products of TNT have been identified in organic solvent extracts of "pink water". Those degradation products that are water soluble (but not extractable by organic solvents) have not been fully characterized; however, as many as thirty components of condensate wastewater (i.e. steam distillates arising from the concentration of "red water" by evaporation) obtained from the Volunteer AAP have been identified and quantified (Table III-1). Other constituents not derived from TNT degradation include the toxicologically significant DNT isomers, particularly 2,4- and 2,6-DNT (Dacre and Rosenblatt, 1974).

VI. HEALTH EFFECTS

Health effects data from human occupational exposure to TNT and from laboratory experiments with animals administered TNT are summarized in this section. Lesions have been observed in many tissues and organ systems including brain, liver, blood, reproductive organs, kidneys, urinary bladder and eyes. Evidence is presented that TNT is both mutagenic and carcinogenic in bacterial and animal tests, respectively.

A. Health Effects in Humans

With the advent of the large scale manufacture of TNT during World War 1, many munitions workers reportedly died of TNT intoxication. During one 7 month period, 475 deaths (2.8%) occurred among 17,000 cases of TNT poisoning. In one munitions plant alone, 105 fatalities (1.5%) occurred among 7,000 cases of TNT intoxication during a 20 month period (Zakhari and Villaume, 1978). Overall, in the four year period between 1914 and 1918, 580 deaths (2.4%) were reported in the United States out of 24,000 cases of known TNT poisonings (Rosenblatt, 1980). In British ammunition plants, 125 deaths (26.3%) over a 25 year period were reported among 475 cases of toxic jaundice resulting from exposure to TNT (Zakhari and Villaume, 1978).

With the increased awareness of the hazards of TNT exposure, the number of fatalities significantly decreased during World War II, despite a dramatic increase in the production of this explosive. Only 22 fatalities were reported in the period between June, 1941 and September, 1945 among all government-owned ordnance explosives plants. Eight (36%) were due to toxic hepatitis and 13 (59%) were due to aplastic anemia (Zakhari and Villaume, 1978). Only one-third of the 22 were exposed to TNT at average concentrations over 1.5 mg/m^3, the existing workplace standard (OSHA, 1981). Among these cases, hepatitis was reported to occur more frequently among younger persons (average age, 30 years), with aplastic anemia being the cause of death among older persons (average age, 45 years). The pathologic findings in the clinical hepatitis cases invariably included degenerative damage to the liver, usually accompanied by a great reduction in size and weight (NRC, 1982).

Since World War II, only occasional deaths due to TNT exposure have been reported and very few problems related to TNT use have been found in the English-language literature (Morton et al., 1976).

In an extensive review of the literature, Zakhari and Villaume (1978) reported on the various signs and symptoms of TNT toxicity and provided detailed descriptions of the more specific effects of TNT on individual body systems. The following is a summary of this report.

Initial exposure to TNT in the atmosphere may result in mild irritation of the respiratory passages (nasal discomfort, sneezing, epistaxis and rhinitis

possibly associated with headache) and skin (erythema and papular eruptions progressing to desquamation and exfoliation). Gastrointestinal disorders, tc include nausea, anorexia and constipation, sometimes associated with tightening of the chest, are among the first signs of possible intoxication. Epigastric pain not associated with food intake is a cardinal symptom.

Absorption of sufficient amounts of TNT through the skin or lungs can produce signs of cyanosis (due to methemoglobin formation), toxic jaundice (due to severe liver damage), aplastic anemia (due to damage to the erythropoietic system), cataract formation (possibly a direct effect of TNT vapor or dust; may be first and only clinical manifestation), menstrual disorders (hypo- or hypermenorrhea), neurological manifestations (neurasthenia, nystagmus, irregularities of tendon reflexes and adiadochokinesia; only 2.2% of the cases in one study manifested diffuse brain lesions; 50% of the persons examined in another study showed irregularities in their thermoregulating reaction to heat and cold (Kaganov et al., 1970 as cited in Zakhari and Villaume, 1978)) and nephrotoxicity (as evidenced by a significant rise in glomerular filtration rate, sodium retention, urgency, frequent micturition and lumbar pain).

Upon physical examination, the findings may include a yellow discoloration of the skin, nails and hair. This is usually due solely to staining with TNT and is not to be confused with the jaundice associated with liver toxicity. More significant would be a bluish discoloration of the mucosa indicative of developing cyanosis. Other physical findings might include dermatitis with or without rash (early appearing rashes may clear), epigastric pain, tenderness and/or spasm, enlarged and palpable liver and changes to the electrocardiogram (bradycardia, decreased amplitude of QRS complex, flattened T-wave) and electroencephalogram (decreased amplitude of biopotentials, slowed activity, poor reaction to stimuli), functional in nature, and apparently due to vascular disturbances in the brain (Ermakov et al., 1969 as cited in Zakhari and Villaume, 1978).

Laboratory findings include an amber to deep red coloration of the urine and various effects on the hematological parameters and blood chemistries. In several cases where TNT exposure resulted in death, specific post-mortem findings included fatty changes in the liver and kidneys. Foulerton (1918) as cited in Zakhari and Villaume (1978) reported that in 3 specific cases of death due to TNT intoxication (exposure level and duration not specified), the liver showed signs of advanced degeneration, disintegration of parenchyma, fibrosis and advanced interlobular round-cell infiltration. Fat was distributed in both parenchyma and fibrotic tissue. The kidney also showed signs of fat accumulation along with cloudy degeneration of the epithelium of the convoluted tubules. The glomeruli were, however, free of fat globules. Numerous fat granules were scattered throughout the interalveolar tissues of the lungs. Masses of brownish material were found in all three organ systems.

While there have been only limited reports in the English literature of

cataract formation resulting from industrial exposure to TNT, Zakhari and Villaume (1978) described several studies that reported the finding of cataracts among European and Russian dynamite workers. The cataracts have been reported to often occur without other toxic manifestations (Manoilova, 1968) while Tyukina (1967) described changes in the crystalline lens as occurring in four stages and being characteristic of TNT-induced opacities, easily distinguishable from those of different origins. Hassman and Juran (1968) reported the occurrence of cataracts in 26/61 (42.6%) workers, average age of 44.5 years, exposed to TNT for an average of 8.4 years. The cataracts were described as V-shaped or lunar, white-grey in color and located in the area of the lens equator. In some cases, the opacities had merged to form an irregular ring. While atmospheric levels were not reported, the authors indicated that cataract formation was not associated with other toxic effects, and that repeated examinations indicated no other health effects in 26.9% of the workers with TNT-related cataracts. In 1978, Hassman et al. confirmed the occurrence of cataracts characteristic of TNT exposure in 87% of a group of 54 TNT workers with previously diagnosed or suspected TNT cataracts. Control subjects were not included in this study. Average exposure duration was approximately 14 years. Other TNT-related effects were minimal, confirmed in only 9% of the exposed group and reported as chronic TNT intoxication.

More recently, Harkonen et al. (1983) reported on the occurrence of equatorial lens opacities in 6 of 12 occupationally exposed workers in Finland. The opacities were described as bilateral and symmetrical. They had no effect on visual acuity or visual fields. They were detectable only in the periphery of the lens, being either continuous or discontinuous. Exposure duration was approximately 6.8 years with workroom air concentrations averaging 0.3 mg/m^3 with a range of 0.14 to 0.58 mg/m^3. Physical examination as well as several blood chemistry parameters were normal. The average age for the 12 workers was 39.5 years with the subgroup having positive cataract findings averaging 43.8 years vs 35.2 years in those without cataracts. In 1984, Makitie et al. reported that 18/21 (85%) workers exposed to TNT for a mean of 12.3 years in the processing and packing of explosives had detectable equatorial lens opacities, most frequently in the anterior cortex of the lens with decreasing density toward central areas. The mean age of the exposed workers was 41.1 years while atmospheric levels ranged from 0.1 to 0.4 mg/m^3. Ten workers showed varying degrees of central opacity, from minute spots to small rosettes, but these opacities were so slight that no effect was detectable on visual acuity. In 50% of those with the peripheral lens opacities, the density was so slight that no shadow was seen in fundus reflex photography. There have been no reports in the literature nor in occupational health surveys on the occurrence of cataracts in munitions workers in the United States.

The mechanism of TNT-cataract formation is not clearly defined. While more recent studies (Harkonen et al., 1983) have investigated radical formation, based upon the vulnerability of the peripheral lens fibers to effects of

peroxidation, as a possible cause of TNT-related cataracts, no definitive conclusions could be drawn from this investigation. Several studies implicate direct contact and local absorption as the probable cause (Kroll and Kolevatykh, 1965; Manoilova, 1967 as cited in Zakhari and Villaume, 1978), based upon the absence of systemic effects in the majority of the exposed individuals with the positive cataract findings. The weak polarity of TNT also supports its ability to directly penetrate the lens.

It has also been found that individuals deficient in glucose-6-phosphate dehydrogenase (G6PD) may be particularly susceptible to TNT intoxication. In one report (Djerassi and Vitany, 1975 as cited in Zakhari and Villaume, 1978), onset of hemolytic episodes occurred in 3 individuals within 2 to 4 days after initial exposure to TNT. Based on these and similar findings, it was recommended that determination of G6PD activity be made a pre-employment requirement for TNT workers.

Effects on the white blood cells (WBCs), as evidenced by an increase in the large mononuclear leukocyte count, may also be an early indicator of TNT poisoning. Hamilton (1946) reported that increases in these cells usually preceeded symptoms of illness and levels remained elevated for 2 to 3 months following initial occurrence (cited in Zakhari and Villaume, 1978).

Toxic hepatitis and aplastic anemia have been reported as the principal cause of death following TNT intoxication. Zakhari and Villaume (1978) reported that several fatal cases of aplastic anemia were associated with earlier episodes of non-fatal toxic jaundice or hepatitis. They further indicated that aplastic anemia can occur after a latent period of several years following an attack of toxic jaundice. Hyperplasia of the bone marrow is the first reaction of the hemapoietic tissues to TNT poisoning.

In a report prepared by the Department of the Army, as guidance standards in industrial medicine and hygiene (DARCOM, 1976), gastrointestinal symptoms were reported as often the first indication of toxicity. This report also indicated the lack of a clear relationship between the occurrence of the dermatitis often associated with exposure to TNT and the development of systemic effects; either may exist in the absence of the other.

Older reports on the adverse health effects associated with exposure to TNT generally did not include information on workplace concentrations. In one uncontrolled study, Ermakov et al. (1969) as cited in NRC (1982), reported that 122 (21%) of 574 employees exposed to an average TNT concentration of 1 mg/m^3 were chronically poisoned; work exposures ranged from 6 to 25 years. Most of those affected had functional disorders of the central nervous system, with 22% (27) having chronic anemia and leukopenia, 20% (24) with cataracts, and 12% (15) with symptoms of hepatitis. No comparisons were made with unexposed control populations.

Several reports of controlled studies have provided some information on the early and subclinical effects of TNT exposure (Stewart et al., 1945, El Ghawabi et al., 1974, and Hathaway, 1974 as cited in NRC, 1982; Morton et al., 1976). A significant finding in these epidemiologic studies is the occurrence of hematologic and hepatic abnormalities at TNT concentrations well below the Permissible Exposure Limit (PEL) of 1.5 mg/m^3 (OSHA, 1981). Among the most persistent findings were mild reductions in hematocrit (Hct), hemoglobin (Hgb) concentrations and red blood cell (RBC) counts of exposed persons. These findings have been attributed mostly to the destruction of red cells by hemolysis due to exposure to TNT or to its metabolites (Voegtlin et al., 1922, Cone, 1944, as cited in NRC, 1982; Hathaway, 1977).

In one study cited by Zakhari and Villaume (1978), a group of 62 undergraduate students were exposed to atmospheric concentrations of TNT ranging from 0.3 to 1.3 mg/m^3 for approximately 33 days (Stewart et al., 1945). Observed changes in 20% or more of the subjects included a decrease in Hgb and circulating blood cells, an increase in the number of reticulocytes, a small but significant decrease in plasma proteins and a significant increase in bilirubin. The authors indicated that males were more susceptible to the hemolytic effects of TNT than were females.

Goodwin (1972) reported that, in a 1951 study at the Lone Star Army Ammunition Plant (LSAAP) in Texarkana, Texas, mean atmospheric contaminant levels for TNT (dust and fumes) were 2.38 mg/m^3, with no exhaust ventilation systems in use. In a series of tests conducted under a Physical Recheck Examination Program, the Thymol Turbidity test, indicative of liver cell irritation, was used to evaluate liver impairment. From a total of 1,537 tests run during one screening period, 87.5% of the workers were within the selected normal range (to 2.9 MacLagen units) with no signs of liver toxicity. Of the remaining workers with liver function tests above the normal range, from 2.9 to >5 MacLagen units, 36 (<2.5%) showed classical symptoms of liver damage. Liver function values in the affected workers, initially >5 MacLagen units, returned to normal limits within three weeks of their removal from the contaminated environment.

In an occupational health study conducted by the U.S. Army Environmental Hygiene Agency (USAEHA) at a TNT washout facility at Letterkenny Army Depot in Pennsylvania, Friedlander et al. (1974) reported that employees exposed for 6 months to TNT at various work locations in the facility and at atmospheric levels ranging from <0.02 to 3.00+ mg/m^3 displayed clinically and statistically significant decreases in Hgb and Hct levels when compared to pre-exposure values. Furthermore, a statistical comparison of these post-exposure values with those of matched controls (non-exposed individuals) at the same facility indicated a higher rate of abnormalities in the exposed individuals and mean value differences between the two groups.

In addition to significant differences in the Hgb and Hct values ($0.005 \leq p \leq$

0.01), significant differences were also found in RBC count and blood urea nitrogen (BUN) ($0.005 \leq p \leq 0.01$) and in reticulocytes, eosinophils and glucose ($0.01 \leq p \leq 0.05$). No significant differences could be demonstrated in several other laboratory parameters including serum glutamic-oxaloacetic transaminase (SGOT), lactic dehydrogenase (LDH), serum alkaline phosphatase (SAP), cholesterol and total bilirubin, among others. It could not be determined from this report if the positive clinical findings were dose dependent.

In another occupational health survey (Morton and Ranadive, 1974) conducted by USAEHA at the Newport Army Ammunition Plant (NAAP), Indiana, the distribution of abnormal values among workers correlated closely with both an increased production rate (from 75% to >100% capacity) and an increase in TNT dust levels (from 0.3 mg/m^3 to 0.8 mg/m^3). Various parameters were tested including Hgb, SGOT and LDH. Based on the measured values, 62.8% of the TNT exposed individuals demonstrated abnormal findings. The detection rate (ability to identify abnormal results) ranged from approximately 26% when only Hgb values were evaluated to 100% when the values for all 3 parameters (Hgb, SGOT and LDH) were assessed. Recovery to normal levels occurred upon removal of the individual from sources of exposure but the time required for recovery could not be determined from the available data. No statistically significant differences could be found in the incidence of abnormalities when results were compared as to sex, age or race, but sampling size may not have been sufficient.

Further statistical analysis of these clinical parameters as measured prior to the time of increased TNT production (atmospheric levels of 0.3 mg/m^3) paired with those one month after production was increased (atmospheric levels of 0.8 mg/m^3) indicated a statistically significant increase in LDH levels ($P < 0.005$) and SGOT levels ($P < 0.01$) following the increase in production rate. No such correlation was seen in hemoglobin levels (Morton et al., 1976). This increase in both the number of individuals with abnormal test results and the degree of the abnormality were correlated with the higher atmospheric levels of TNT, leading the authors to question the suitability of the Threshold Limit Value (TLV) of 1.5 mg/m^3 recommended at that time (ACGIH, 1971).

In a follow-up to the two previously cited occupational health surveys at Army facilities, USAEHA performed a cross-sectional epidemiological study involving 626 employees exposed to one or more munition compounds (TNT, RDX[a/], HMX[b/]) and 865 non-exposed employees from 5 Army Ammunition Plants[c/] (Buck and Wilson, 1975). All individuals were evaluated for liver function (SAP, SGOT, serum glutamic-pyruvic transaminase (SGPT) and bilirubin) and hematological

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a/ cyclotrimethylenetrinitramine (1 hexahydro-1,3,5-trinitro-1,3,5-triazine)

b/ cyclotetramethylenetetranitramine (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazoline)

c/ Joliet, Iowa, Milan, Volunteer and Holston

(Hgb, Hct and reticulocyte count) abnormalities. No evidence of liver toxicity was indicated by the parameters studied. This result appears to be in contrast to the positive findings of liver toxicity in the NAAP study. However, exposure levels in this cross-sectional study were generally <0.5 mg/m^3 with only approximately 12% of the TNT workers exposed at levels >0.5 mg/m^3 while at NAAP, exposure levels rose to approximately 0.8 mg/m^3. Accordingly, the authors indicated that 0.5 mg/m^3 may be considered a reasonable no effect level for hepatotoxicity.

On the other hand, a significant hematological effect was observed among TNT workers exposed in this cross-sectional study to atmospheric levels of <0.5 mg/m^3. This positive effect was evidenced by a dose response relationship for all three parameters and occurred more readily among males. These results suggested to the authors that low level TNT exposure (<0.5 mg/m^3) may induce a low grade hemolysis with a compensatory mild reticulocytosis. It was not possible to determine a no effect level for hematological effects from the study. As a result of this study, USAEHA recommended that the TLV for TNT in the work place be lowered from the existing level of 1.5 mg/m^3 to a level of 0.5 mg/m^3 and that the U.S. Army adopt 0.5 mg/m^3 as their airborne exposure standard for TNT.

B. Health Effects in Animal Experiments

1. Short-Term Exposure

As indicated by studies in rats, mice and dogs for periods up to four weeks, dietary intake of TNT resulted in early but not persistent decreases in body weight and food intake while the red pigmentation in the urine persisted throughout. Some anemia was evident but somewhat inconsistent while hemosiderosis of the spleen was seen in all three species. Rats developed testicular atrophy. Table VI-1 summarizes these toxicity studies.

Lee et al. (1975) determined the acute oral toxicity of TNT in Charles River CD rats and albino Swiss mice. Rats and mice were fasted for at least 16 hours prior to dosing by intragastric intubation with a 4.12% saturated solution of TNT in peanut oil. After treatment, the survivors were observed daily for 14 days for delayed mortality or toxic signs. The LD_{50} was calculated by a computer program based on the method of maximum likelihood of Finney (1971).

The acute LD_{50} values in male and female rats were 1,010 and 820 mg/kg, respectively; in male and female mice they were 1,014 and 1,009 mg/kg, respectively. Symmetrical coordinated convulsions associated with respiratory inhibition occurred within 5 to 15 minutes after dosing and continued for 1 to 2 hours. Death, when it occurred, was usually due to respiratory paralysis while survivors appeared cyanotic and exhibited ataxia. Recovery was complete in 24 to 48 hours. No gross pathology attributable to treatment was noted.

16.0 OPERATIONS MANUAL

16.0 Operations Manual

16.1 Process Description

Red water is fed to the CBC where it is thermally treated. Combustion by-products (ash) and bed material are indirectly cooled with water in the ash cooler conveyor. The combustion gas is cooled in the partial quench and cleaned in the baghouse.

The feed system conveys red water to the CBC. The red water enters the CBC at the loop-seal. Mixing and blending occur inside the CBC because of the turbulence of the combustion air and the circulating media.

The auxiliary fuel is natural gas, which can be fired in the start-up burner or fed directly to the CBC. The start-up burner is mounted in the CBC wind box and has a maximum capacity of 5 MMBtu/hour.

At temperatures greater than 1300°F, auxiliary fuel is fed directly to the CBC, where 4 MMBtu/hour of auxiliary fuel can be fed directly to the CBC.

Primary air is provided to the start-up burner by the combustion air blower. Fluidizing air (secondary air) is fed directly to the CBC wind box by the combustion air blower. The quantities of fuel and air fed to the CBC are carefully monitored and controlled to maintain the CBC combustion chamber flow rate and temperature.

Ash and bed material are discharged from the CBC by the ash cooler conveyor. The CBC off-gases are ducted to the partial quench where they are cooled to about 400°F. The cooled combustion gases pass through the baghouse where more than 99 percent of the particulate is removed. The cleaned combustion gases then pass through the I.D. fan and exit at the stack.

The components of the CBC system are illustrated on the PFD D-00-10-001. This drawing includes a typical M&EB for the CBC system and the design flows and conditions. The

piping, instrumentation, and controls associated with the CBC are shown in the following P&IDs:

- D-20-11-001
- D-20-11-002
- D-50-11-001.

16.2 Process Control Description

16.2.1 Process Control Overview

The CBC thermally treats red water and produces ash. The CBC operates with a constant flow rate of combustion gases in the CBC combustion chamber. Ash and bed material is discharged into the ash cooler conveyor for cooling and storing. Ash from the baghouse is discharged through four rotary valves into a storage bin.

Combustion gases from the combustion chamber pass through a cyclone that separates the entrained bed material from the combustion gases. The bed material is returned to the combustion chamber through the loop-seal. The CBC off-gases exit the CBC by a refractory-lined duct that connects the CBC to the partial quench. The partial quench cools the combustion gases to approximately 400°F. The cooled combustion gases go to the baghouse where more than 99 percent of the particulate is removed. The cleaned combustion gases then pass through the I.D. fan and exit from the stack.

A negative pressure is maintained in the CBC by adjusting the inlet vane damper to the I.D. fan. The combustion gas flow rate in the combustion chamber is maintained by adjusting the damper on the combustion air blower. The dP across the bed is maintained by adding or removing bed material from the CBC.

The CBC uses natural gas as the auxiliary fuel. Combustion chamber temperature is controlled by adjusting the auxiliary fuel firing rate. The partial quench exit gas temperature is controlled by varying the quench water flow rate.

The red water feed rate to the CBC is controlled by a control valve in the feed line. The red water feed rate is limited by the concentration of oxygen in the stack.

16.2.2 CBC Start-Up Burner System Controls

The air-to-fuel ratio in a burner is critical to the safe operation of a combustor. The air-to-fuel ratio for the CBC start-up burner is strictly based on the flow rate of natural gas to the main burner. The combustion air is provided by the combustion air blower. The fuel flow signal is transmitted to the air-to-fuel ratio controller (FFIC-204) in the central control system (CCS). Based on the ratio set by the operator, the FFIC-204 (ratio controller) modulates the damper (FV-204) on the combustion air blower discharge, modulating the primary air flow.

Start-Up Burner Flameout. A flame scanner (BE-209) scans the start-up burner. When flame scanner BE-209 detects that the CBC start-up burner flame is extinguished, the following results occur:

- Fuel gas (natural gas) is isolated from the CBC via double block and bleed Maxon valves YV-209A, B, and C.

- Primary combustion air control valve (FV-204) goes to its low fire position.

16.2.3 CBC Primary Fuel System Controls

At temperatures greater than 1300°F, the auxiliary fuel will be fed directly to the CBC. At these temperatures, the auxiliary fuel, natural gas, will autoignite; therefore, standard burner management practices are not practical or required.

Primary Fuel Air-to-Fuel Ratio Control. The air flow rate to the CBC is adjusted to control the combustion gas velocity in the combustion chamber. The only adjustment of the primary fuel air-to-fuel ratio is the minimum oxygen limit at the stack.

Primary Fuel Flameout. The primary fuel will be fed directly to the CBC at temperatures greater than 1300°F, which is more than the autoignition temperature of natural gas.

Therefore, a primary fuel flameout is impossible and there are no flame detection devices used or required.

16.2.4 CBC Combustion Chamber Temperature

The CBC combustion chamber temperature is controlled by modulating the amount of auxiliary fuel added to the combustion chamber. Because of the long solids retention time (typically more than 20 minutes), the ash temperature is equal to the combustion chamber temperature.

The CBC combustion chamber temperature is sensed by two redundant thermocouples (TE-203A and B) located in the CBC combustion chamber. During routine operation, the circulation of the bed media tend to equalize the temperature throughout the CBC. The temperature will be relatively constant in the combustion chamber, the cyclone, and the loop-seal.

During routine operation, the CBC combustion chamber temperature is controlled by modulating the flow of auxiliary fuel to the CBC. If the gas temperature falls, temperature controller TIC-203 will increase the flow of auxiliary fuel to the CBC by flow controller FIC-219, which controls the auxiliary fuel valve (FV-219).

16.2.5 CBC Combustion Chamber Pressure Control

The pressure inside the CBC is maintained slightly below atmospheric pressure. CBC pressure is sensed by PIT-210 located in the loop-seal. The pressure is controlled by PIC-210, which adjusts the pressure control valve (PY-501).

16.2.6 Differential Pressure Across the Bed

For proper operation of the CBC, it is necessary to maintain the appropriate dP across the bed and to routinely provide fresh material to the bed. The dP across the bed is measured by PDIT-206. The dP across the bed is increased by adding bed material and is decreased by operating the ash cooler conveyor (H-2001).

16.2.7 Combustion Gas Velocity

The combustion gas velocity is maintained at a constant 5,030 acfm. This velocity is measured by a portable pilot-tube at the exit of the cyclone. Flow controller (FFIC-204) adjusts the flow valve (FV-204) to control the combustion gas velocity.

16.3 CBC System Start-Up

16.3.1 Introduction

The procedures provided in this section are supplements to the procedures that will be described in the equipment vendors' manual. The procedures in the vendors' manual should be consulted and followed as appropriate.

The following utilities must be available before attempting to start this area of the plant:

- Electrical power - normal and uninterrupted power supply (UPS)
- Instrument air
- Plant air
- Auxiliary fuel - natural gas.

16.3.2 Start-Up Procedure Summary

16.3.2.1 Cold Start Procedure Summary

The following summary procedure assumes that the CBC refractory does not require curing:

1. Check that the ash system is operational.

2. Start the combustion air blower (B-2001) by pushing the start button (HS-204).

3. Start the I.D. fan (B-5001) by pushing the start button (HS-501).

4. Start the loop-seal blower (B-2002) by pushing the start button (HS-207).

5. Add the bed material to the CBC until the dP across the bed is more than 20 in. w.c. on PDIT-206.

6. Check that water is available to the quench.

7. Check that process air is available to the baghouse.

8. Light the start-up burner by pressing the start button.

9. Gradually increase natural gas flow manually to the start-up burner according to the recommended refractory heat up schedule.

10. When the CBC reaches 1300°F, put the start-up burner in manual (FIC-209).

11. Initiate the flow of primary fuel to the CBC by pressing HS-219.

12. Gradually increase the flow of primary fuel (FIC-219) to the CBC until the start-up burner is at low-fire.

13. Shut off the start-up burner.

14. Increase primary fuel firing rate manually until all normal operating set points are met (e.g., 1600°F in the CBC combustion chamber temperature).

15. After all set points are met, start the red water feed at a reduced rate. Monitor CBC combustion chamber temperature manually by adjusting the primary auxiliary fuel firing rate using FIC-219. Watch for slagging and overheating of the CBC.

16. Gradually increase the red water feed rate while monitoring the stack gas oxygen concentration. The maximum red water feed rate will be obtained when the feed rate is equal to the permit feed limit or the stack oxygen/ concentration is equal to 3 percent oxygen.

17. Adjust TIC-203 output to agree with FIC-219 set point, and switch FIC-219 to automatic/cascade control. Switch TIC-203 to automatic/local with its set point agreeing with the exit gas temperature. TIC-203 will then modulate the set point to FIC-219 to increase or decrease the firing rate to the start-up burner to maintain CBC off-gas temperature at the set point.

16.3.2.2 Hot Start Procedure Summary

After an emergency shutdown, the CBC can be restarted as follows:

1. Check that all combustion air blowers are operating.
2. Check that the CBC ancillary equipment is operating.
3. Re-light the start-up burner.
4. Re-establish CBC temperature and waste feed rate by following the last eight steps in Section 16.3.2.1, Cold Start Procedure Summary.

16.3.2.3 Start-Up During Hot Idle

To start-up from hot idle, follow Steps 10 through 17 of Section 16.3.2.1, Cold Start Procedure Summary.

16.3.2.4 Refractory Curing

General Information. The main purpose for drying out a CBC or any other piece of refractory-lined process equipment before making it operational is to remove the residual moisture in the brick, mortar, and castable. This moisture must be removed slowly enough to ensure that steam is not generated within the lining. Such steam generation can rupture the lining and cause the refractory to fracture.

The general and recommended practice is to heat the refractory-lined equipment slowly, bringing the temperature up gradually and in specific increments. As the temperature is raised, it is also kept at certain levels for specified lengths of time.

When the drying out process is completed, it is desirable for the plant to be in a position to raise temperature to process levels and to go into production.

The entire drying out process has to be coordinated and a close check kept on all of the temperature-indicating devices in the system to ensure that temperatures at any point do not exceed equipment capabilities.

Equipment to be Dried Out. The following pieces of equipment are refractory-lined and will require various degrees of drying out:

- CBC - including combustion chamber, cyclone, and loop-seal
- Discharge duct
- Quench.

Drying Out. All of the equipment can be dried out by introducing heat through the start-up burner. Follow system start-up procedure provided in Section 16.3.2.1, Cold Start Procedure Summary, to light the burner. The CBC, the discharge duct, and the quench can be cured simultaneously.

The following drying schedule is to be followed unless the supplier's recommendations are more stringent:

1. After all refractory work has been completed, let it air dry for at least 24 hours. If there is any visible moisture on the refractory surface, such as wet grout, continue air drying.

2. Using the start-up burner at a very low setting, hold the CBC combustion chamber temperature at 150°F as shown on the CBC exit thermocouple for 12 hours. Combustion air flow rate can be used to help keep the temperature down.

3. With the start-up burner, raise the temperature approximately 50°F per hour to 300°F (3 hours).

4. Hold the temperature at 300°F for 12 hours.

5. Increase the temperature 50°F per hour to 600°F (6 hours).

6. Hold the temperature at 600°F for 12 hours.

7. Increase the temperature 50°F per hour to 1000°F (8 hours).

8. Raise the CBC combustion chamber temperature (now at 1000°F) approximately 50°F per hour to 1250°F (5 hours) and hold at 1250°F for 6 hours.

9. Raise the CBC combustion chamber temperature approximately 50°F per hour to 1500°F (5 hours). The refractory should now be dry and the equipment should be ready to be put into operation. It is recommended that the equipment be put into operation without cooling the refractory. If the equipment is not going to be put into operation, begin cool down at a rate of 50°F per hour.

Cautions:

- During dryout, be especially careful not to exceed temperature limitations of other equipment in the system (fan, scrubber, etc.).

- If steam is noticed during the dryout, hold at that temperature until the steaming stops.

- If the dryout is interrupted, restart the dryout at the last fully completed portion of the dryout schedule.

- Do not shock refractory with either heat or cold; gradually heat up or cool down refractory at approximately 50°F per hour.

- If installed refractory material gets wet, gradually heat it up and dry it out at approximately 50°F per hour. If steam is noticed during heat-up/dryout, hold at that temperature until the steaming stops.

17.0 PERFORMANCE TEST PLAN

17.0 Performance Test Plan

17.1 Introduction

Red water is the aqueous effluent generated during sellite purification of crude TNT. Red water is a reactive hazardous waste, EPA Hazardous Waste number K047. To destroy red water, a CBC is being designed.

After construction of the CBC is completed, the unit will be started and operational defects identified and corrected. When the CBC is operationally ready, the test program will commence. The test program is designed to optimize the performance of the CBC and to demonstrate the ability of the CBC to meet regulatory and warranty performance limits.

The test program will consist of three distinct test phases:

- Start-up test
- Shakedown test
- Performance test.

17.1.1 Start-Up Test

After construction of the CBC is completed, the unit will be started on auxiliary fuel and the mechanical, electrical, instrumentation, and control system will be checked out.

17.1.2 Shakedown Test

After the completion of the start-up test, the shakedown test will begin. During the shakedown test, the optimum CBC operational parameters and the performance limits will be determined. The shakedown test will have two separate segments:

- Tests that can be conducted when operating on only auxiliary fuel
- Tests that require the CBC to be combusting auxiliary fuel and red water.

17.1.3 Performance Test

The performance test will be conducted on the CBC after the completion of the shakedown test. During the performance test, the CBC will be tested for its ability to meet regulatory and warranty performance requirements.

This document presents the basic outline for the start-up, shakedown, and performance tests, and is not intended to serve as the Trial Burn Plan. A separate Trial Burn Plan must be prepared during the RCRA permitting process.

17.2 CBC Process Description

17.2.1 Type of Incinerator

The CBC incinerator consists of a combustion chamber, a hot cyclone, and a loop-seal. Bed material is fluidized with air in the combustion chamber. The bed material is blown out of the combustion chamber to the hot cyclone. The hot cyclone separates the combustion gases and the bed material. The bed material is sent to the loop-seal and returned to the combustion chamber. The combustion gases exit the cyclone to the APCS.

17.2.2 Description of the Auxiliary Fuel System

The start-up burner is a 5 MBtu/hr burner mounted in a duct attached to the wind box. This burner uses natural gas as the auxiliary fuel to heat the combustion air. At temperatures above 1300^{o}F, the auxiliary fuel (natural gas) is fed directly to the tuyeres.

17.2.3 Capacity of the Prime Mover

The CBC prime mover is an induced draft fan rated at 5,000 acfm at 50 inches water column.

17.2.4 Description of the Waste Feed System

The CBC is designed to thermally treat red water. The red water is fed by a pump to the feed port located on the loop-seal.

17.2.5 Treated Material Handling System

Treated material (ash and spent bed material) from the CBC drops into the ash cooler conveyor. The ash cooler conveyor is a screw conveyor that cools the ash and places the ash in the ash bin.

17.2.6 Description of the Automatic Waste Feed Cutoff System

The primary function of the automatic waste feed cutoff (AWFCO) system is to prevent the feeding of red water if the CBC process conditions are outside of the permitted operating limits. During the start-up and shutdown of the incinerator or during process upsets, the interlocks automatically stop all waste feed systems and prevent their restart until the CBC is within the required operating limits.

When waste feeds are stopped due to an AWFCO interlock, auxiliary fuel (natural gas) will continue to be fired to maintain operating temperatures. With the exception of the waste feed components, the system will remain entirely operational. Waste feeds will not be restarted until the problem that caused the AWFCO condition has been resolved and all operating permissives are achieved (as with a normal start-up).

A discussion of the proposed AWFCO parameters follows. The actual values for each of these parameters may vary during the detailed design of the CBC.

- Combustion Chamber Temperature - The combustion chamber temperature is measured by a shielded thermocouple located in the CBC bed material. When the combustion chamber temperature falls below 1500 °F or rises above 1700°F, the red water feed to the CBC will be automatically stopped.

- Maximum Combustion Chamber Pressure - To prevent fugitive emissions, if the pressure in the CBC exceeds minus 0.08 in. w.c., as measured at the feed port in the loop-seal, all waste feeds will be automatically stopped.

- Combustion Gas Temperature After the Quench - The quench cools and saturates the hot gases exiting the CBC. This prevents damaging the bags in the baghouse with hot combustion gases. If the gases leaving the quench chamber exceed 450 °F or the filter bag manufacturer's recommended temperature limit, the waste feeds will be automatically stopped.

- Combustion Gas Velocity (CGV) - A flow sensor located in the stack after the I.D. fan will measure the CGV. All waste feeds will be automatically stopped if the CGV exceeds 3,500 acfm on a 10-minute rolling average basis.

- Carbon Monoxide - CO concentrations are measured in the stack. All waste feeds will be automatically stopped if the CO concentration exceeds 100 ppm on a 1-hour rolling average, corrected to 7 percent O_2, dry basis.

- Additional parameters determined during detailed design and/or preparation of the trial burn plan.

17.2.7 Combustion Gas Monitoring and Air Pollution Control System

Combustion Gas Monitoring. The combustion gas is continuously monitored for CO and O_2 in the stack.

Air Pollution Control System. In the APCS, the combustion gases are partially quenched and filtered to remove particulates. An I.D. fan maintains sub-atmospheric pressures throughout the incineration system and provides the motive force for the scrubber system.

The major equipment components that comprise the air pollution control system include the:

- Partial quench
- Baghouse
- I.D. fan
- Stack

The quench column uses water to cool the combustion gas from the combustion chamber temperature to approximately 400°F. The particulate in the cooled combustion gases are then removed in the baghouse. The I.D. fan provides a negative draft on the CBC system and pulls the combustion gas through the APCS.

17.3 Start-Up Test

After completion of the construction of the CBC, the incinerator will be started on auxiliary fuel. The CBC start-up operating conditions are presented in Table 17-1. These values may be modified during the detailed design of the CBC.

Table 17-1

Start-Up and Interim Operating Conditions

Parameter	Operating Condition[a]
Group A Parameters	
Minimum CBC temperature	1500°F
Maximum CBC temperature	1800°F
Maximum CBC pressure	-0.08 in. w.c.
Maximum red water feed rate	1.5 gpm
Maximum combustion gas velocity (10-minute rolling average)	3,450 acfm
Maximum stack gas CO concentration (1-hour rolling average, dry basis, corrected to 7% oxygen)	100 ppm
Group B Parameters	
POHC incinerability limits	To Be Determined[b]
Maximum chlorine feed rate	To Be Determined[b]
Maximum antimony feed rate	To Be Determined[b]
Maximum arsenic feed rate	To Be Determined[b]
Maximum barium feed rate	To Be Determined[b]
Maximum beryllium feed rate	To Be Determined[b]
Maximum cadmium feed rate	To Be Determined[b]
Maximum chromium feed rate	To Be Determined[b]
Maximum lead feed rate	To Be Determined[b]
Maximum mercury feed rate	To Be Determined[b]
Maximum silver feed rate	To Be Determined[b]
Maximum thallium feed rate	To Be Determined[b]
Group C Parameters	
Maximum combustion gas temperature after the quench	450°F

[a]The values given in this table are estimates that may vary during the actual trial burn.
[b]To be determined during the preparation of the Trial Burn Plan.

During the start-up of the CBC, all of the mechanical, electrical, instrumentation, and control systems will be checked for conformance with the design and warranty specifications. The specific requirements of the start-up test program will be determined during the CBC detailed design.

17.4 Shakedown Testing

After the completion of the start-up testing, the shakedown testing will occur. RCRA regulations stipulate that the CBC may be operated on red water for up to 720 hours before the trial burn. Therefore, the shakedown testing will be divided into two types of tests: tests that can be conducted on auxiliary fuel only and tests that require the combustion of the waste stream (red water) in addition to the auxiliary fuel.

17.4.1 Tests to be Conducted When Operating on Auxiliary Fuel Only

All of the shakedown testing to be conducted while operating on only auxiliary fuel should be completed before red water is fed to the CBC. The following operational parameters will be studied while only operating on auxiliary fuel:

- Optimal Bed Depth - The bed depth is measured as the pressure drop across the combustion chamber. The greater the pressure drop, typically measured in in. w.c., the greater the bed depth. If the bed depth is too low, the CBC bed material will not circulate properly. If the bed depth is too high, greater quantities of bed materials will be carried over to the APCS, increasing the particulate burden to the APCS and requiring frequent addition of fresh bed material to the combustion chamber. During the shakedown testing, the impact of variations in the bed depth to the performance of the CBC and the APCS will be studied and the optimum operational ranges determined.

- Optimum Gas Velocity in the CBC - The gas velocity in the combustion chamber of the CBC will be studied. If the gas velocity is too low, the CBC bed material will not circulate properly. If the gas velocity is too high, greater quantities of bed materials will be carried over to the APCS, increasing the particulate burden to the APCS and requiring frequent addition of fresh bed material to the combustion chamber. During the shakedown testing, the impact of variations in the gas velocity to the performance of the CBC and the APCS will be studied and the optimum operational ranges determined.

- Loop-Seal Performance - The performance of the loop-seal at varying loop-seal fluidizing are flow rates will be assessed.

- Optimum Air to Cloth Ratio in the Baghouse - By closing off baghouse bags or a baghouse module, the air to cloth ratio in the baghouse will be varied. The impact of the variations in the air to cloth ratio on baghouse performance will be determined.

17.4.2 Tests to be Conducted When Operating on Auxiliary Fuel and Red Water

The following parameters will be studied during the shakedown testing while combusting red water and auxiliary fuel:

- CEM Performance - A relative accuracy test audit (RATA) will be conducted on the CEMs. The RATA will follow the procedures presented in 40 CFE 60 Appendix B and *Methods Manual for Compliance with the BIF Regulations,* EPA/530-SW-91-010.

- Appropriate Bed Material Selection - The optimum bed material is resistant to abrasion and chemically neutral. Bed materials that are not resistant to abrasion will increase the particulate burden to the APCS and require frequent additions of bed material to the CBC. Bed materials that are not chemically inert will chemically combine with components in the waste feed to form low melting point materials. These low melting point materials will lead to the solidification of the bed material, and the resulting shutdown of the CBC for removal of the aggregate solid bed material. During the shakedown testing, the selected bed material will be tested for resistance to abrasion and the formation of eutectic mixtures.

- Use of Limestone to Reduce sulfur dioxide (SO_2) Emissions - During the start-up testing, the SO_2 emissions will be measured and compared to regulatory criteria. If the SO_2 emissions are greater than the regulatory criteria, then the impact of limestone addition to the SO_2 emissions will be studied and a decision made on whether to add limestone to the bed material or to inject lime slurry into the quench. The quantity of limestone or lime slurry to use will also be determined.

- System Turndown Capability - During the shakedown testing, the ability of the CBC to operate in a stable manner at varying waste feed rates will be studied. From this study, the minimum waste feed rate will be determined.

- Evaluate System Performance - The ability of the CBC to operate and the trial burn operational limits will be studied before the start of the formal trial burn

- Evaluate System Performance - The ability of the CBC to operate and the trial burn operational limits will be studied before the start of the formal trial burn program. During the trial burn, the operational performance of the CBC will be compared to regulatory and warranted performance criteria. From this test, the maximum waste feed rate will be determined.

- Precoating the Baghouse Bags With Lime - The high moisture of the combustion gases may cause poor baghouse operational reliability. A test will be conducted to determine if precoating the baghouse bags with lime will increase the operational reliability of the baghouse.

After completion of the shakedown testing, the optimum operating conditions and the performance limits will be known.

17.5 Performance Testing

The performance test will be conducted on the CBC after start-up and shakedown testing are completed. During the performance test, the CBC will be tested for its ability to meet regulatory and warranty performance requirements. The objective of the performance test is to obtain data that will:

- Demonstrate greater than 99.99 percent of POHCs.

- Confirm the fate of POHCs fed to the CBC; they are either destroyed by thermal oxidation or emitted in the stack gases, ash residues, or scrubber water purge stream.

- Demonstrate that the emissions of carbon monoxide (CO) are less than 100 parts per million, volume, (ppmv) corrected to 7 percent oxygen (O_2) or, if the stack gas CO is greater than 100 ppmv corrected to 7 percent O_2, the stack gas concentrations of THC do not exceed 20 ppmv.

- Demonstrate control of particulate emissions to less than 0.015 grains per dry standard cubic foot (gr/dscf) corrected to 7 percent O_2.

- Demonstrate compliance with the hydrochloric acid gas (HCl), chlorine (Cl_2), and SO_2 emission standards.

- Determine the emission rates of speciated volatile and semivolatile organics.

- Demonstrate compliance with the metals emissions criteria.
- Determine the emission rate of NO_x.
- Determine the stack concentrations of O_2, CO, and THC.
- Provide process information necessary to determine the suitability of the CBC in the destruction of red water.
- Demonstrate compliance with RCRA and other regulatory performance requirements.

17.5.1 Sampling Locations and Procedures

The locations where liquid and gaseous samples are collected are described in Table 17-2.

The sampling equipment, procedures, frequency, and methods for collecting samples at each point are summarized in Table 17-2. Process and stack gas sampling procedures are further described in the following section.

During the performance test, the stack gases will be sampled for the constituents listed below with the indicated sampling trains:

- Metals emissions using a multi-metals train (MMT)
- POHCs and PICs using a Modified Method 5 (MM5) sampling train and a volatile organic sampling train (VOST)
- HCl/Cl_2/particulate using an EPA Method 0050 (M0050) sampling train.

The CO, O_2, NO_x, and SO_2 concentrations in the combustion gas will be continuously monitored using process CEMs. The stack gas will also be analyzed for CO_2 and O_2 by Orsat analysis during each run.

Table 17-2

Performance Test Sample Collection Locations, Equipment, and Methods

Location	Description	Access	Equipment	General Procedure/Frequency[a]	Reference Methods[b]
Liquid Waste Feed Line	Red Water	Tap	Glass bottle	Grab sample at 30 minute intervals of each run, and composite by run	S004, SW846
Ash Discharge Chute	CBC Ash	Discharge Chute	Glass bottle, scoop	Grab sample at 30 minute intervals of each run, and composite by run	S004, SW846
Baghouse	Baghouse Ash	Baghouse Discharge	Glass bottle, scoop	Grab sample at 30 minute intervals of each run, and composite by run	S004, SW846
Stack	Combustion Gas	Port	MMT	Collect integrated samples for metals and moisture; measure stack gas velocity, pressure, and temperature; collect bag samples for Orsat oxygen (O_2) and carbon dioxide (CO_2)	EPA Method SW0010, EPA Method 0012, EPA Methods 1-5, EPA Guidance
Stack	Combustion Gas	Port	MM-5	Collect integrated samples for PICs, moisture, and dioxins and furans; measure stack gas velocity, pressure, and temperature; collect bag samples for Orsat oxygen (O_2) and carbon dioxide (CO_2)	SW0010, EPA Method 23, EPA Methods 1-5, EPA Guidance
Stack	Combustion Gas	Port	VOST	Four pairs of sorbent cartridges collected for volatile PICs	Method SW0030
Stack	Combustion Gas	Port	HCl sampling train	Collect integrated samples for particulates, HCl, Cl_2 and moisture, measure stack gas velocity, pressure, and temperature, collect bag samples for Orsat oxygen (O_2) and carbon dioxide (CO_2)	EPA Method 0050, EPA Methods 1-5
Stack	Combustion Gas	Port	Instrument sensor	Continuously monitor carbon monoxide and oxygen	Continuous nondispersive infrared; continuous paramagnetic

[a] All samples from aborted runs will be archived.
[b] Prefix "S" refers to Sampling and Analysis Methods for Hazardous Waste Combustion, EPA-600/8-84-002. "SW" refers to Test Methods for Evaluating Solid Waste, SW 846, Third edition, September 1986.

17.5.2 Analytical Procedures

The analyses planned for each performance test sample are listed in Table 17-3. The samples from the MMT will be analyzed for antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, silver, and thallium.

The samples from the MM5 train will be analyzed for the compounds listed in Table 17-4 and the samples from the VOST will be analyzed for the compounds listed in Table 17-5.

17.5.3 Performance Test Protocol

17.5.3.1 Waste Characterization

Red water is the aqueous effluent generated during sellite purification of crude TNT. Red water has a deep red, or sometimes black, color and is a complex and somewhat variable mixture of solid inorganic salts and nitrobodies in water. Depending on the TNT production process and the degree of water recycle use, red water generally contains 15 to 30 percent solids, has a pH of 7 to 9.7, a heat content of 487 Btu/lb, and a specific gravity of 1.1. Approximately one-half of the solids are inorganic salts and the rest are nitrobodies. The typical chemical composition of the red water solids is presented in Table 17-6. The elemental composition of the red water is presented in Table 17-7.

17.5.3.2 Target Operating Conditions

The target operating conditions during the performance test are presented in Table 17-8 and described below.

CBC Temperature. The target CBC temperature is presented in Table 17-8.

Combustion Chamber Pressure. The maximum combustion chamber pressure is presented in Table 17-8.

Red Water Waste Feed Rate. The target liquid waste feed rates for the performance test are presented in Table 17-8. If red water is not available during the performance test, a

Table 17-3

Summary of Analytical Procedures and Methods

(Page 1 of 2)

Analysis	Sample Name	Test Sample Matrix	No. of Samples[a]	Procedure Description	Reference Method[b]
Density	Red Water	Water	3	Gravimetric/volumetric	ASTM D-1429
Heat Content	Red Water	Water	3	Bomb Calorimeter	ASTM D-2015
Ash Content	Red Water	Water	3	Combustion in muffle furnace	ASTM D-482
Total Chlorine	Red Water	Water	3	Ion chromatography of residue	ASTM D-808/E-442
Moisture	Multi-Metals/Particulate	Stack condensate	3	Volumetric/gravimetric	EPA Method 4
	Chromium (VI)	Stack condensate	3	Volumetric/gravimetric	EPA Method 4
	MM-5	Stack condensate	3	Volumetric/gravimetric	EPA Method 4
	M0050 Train	Stack condensate	3	Volumetric/gravimetric	EPA Method 4
Semivolatile Organics[c]	Red Water	Water	3	Extraction, GC/MS	SW 8270
	CBC Ash	Combustion Residue	3	Extraction, GC/MS	SW 8270
	Baghouse Ash	Solid	3	Extraction, GC/MS	SW 8270
	MM-5 Semivolatile	Stack condensate, impinger catches, XAD-2, filter, probe rinses	3	Extraction, GC/MS	SW 8270
Dioxins/Furans	MM-5 Semivolatile	XAD-2, probe rinses	3	Extraction, concentration, GC/high resolution mass spectrometry	EPA Method 23, SW 8290, SW 3540
Metals	Red Water[d]	Water	3	Digestion, ICAP	SW3010/6010, SW 7470
	Metals Spike Solutions[d]	Water	9	Digestion, ICAP	SW3010/6010
	CBC Ash	Combustion Residue	3	Digestion, ICAP	SW3010/6010, SW 7470
	Baghouse Ash	Solid	3	Digestion, ICAP	SW3010/6010
	Multi-Metals/Particulate[d]	Impinger catches, probe rinses, filter	3	Digestion, ICAP	SW3010/3050/6010, SW 7470
HCl/Cl_2 Gas	M0050 Train	Impinger catches	3	Ion Chromatography	SW 846, EPA Method SW-9056
Particulates	Multi-Metals/Particulate	Probe rinse, filter	3	Gravimetric	EPA Method 5
O_2, CO_2	ORSAT sample	Stack gas	9	Integrated bag sample for Orsat analysis	EPA Method 3

Table 17-3

(Page 2 of 2)

Analysis	Sample Name	Test Sample Matrix	No. of Samples[a]	Procedure Description	Reference Method[b]
O_2	CEMs	Stack Gas	-	Continuous Monitor	Paramagnetic[e]
CO	CEMs	Stack Gas	-	Continuous Monitor	Nondispersive Infrared[e]

[a]QC samples are not included in the total.
[b]The following abbreviations were used:
"ASTM" refers to American Society for Testing Material Standards.
"EPA" refers to New Source Performance Standards, Test Methods and Procedures, Appendix A, 40 CFR 60.
"SW" refers to Test Methods for Evaluating Solid Waste, SW 846, Third Edition, November 1986.
[c]The red water, CBC ash, and baghouse ash will be analyzed for POHCs; the MM5 semivolatile train samples will be analyzed for POHCs, dioxins/furans, and the compounds presented in Table 17-4.
[d]Metals limited to: Sb, As, Ba, Be, Cd, Cr, Pb, Hg, Ag, and Tl
[e]The CEM methods are found in 40 CFR 60, Appendix B, Federal Register, Volume 54 No. 206, October, 1989, and the Methods Manual for Compliance with the BIF Regulations Burning Hazardous Waste in Boilers and Industrial Furnaces, USEPA, December, 1990.

Table 17-4

Summary of Semivolatile Compounds for Analysis[a]

Phenol	bis(2-Chloroethyl)ether	2-Chlorophenol
1,3-Dichlorobenzene	1,4-Dichlorobenzene	Benzyl alcohol
1,2-Dichlorobenzene	2-Methylphenol	4-Methylphenol
Hexachloroethane	bis(2-Chloroisopropyl)ether	N-Nitroso-di-n-propylamine
Nitrobenzene	Isophorone	2-Nitrophenol
2,4-Dimethylphenol	Benzoic acid	bis(2-Chloroethoxy)methane
2.4-Dichlorophenol	1,2,4-Trichlorobenzene	Naphthalene
4-Chloroaniline	Hexachlorobutadiene	4-Chloro-3-methylphenol
2-Methylnaphthalene	Hexachlorocyclopentadiene	2,4,6-Trichlorophenol
2,4,5-Trichlorophenol	2-Chloronaphthalene	2-Nitroaniline
Dimethyl phthalate	Acenaphthylene	2,6-Dinitrotoluene
3-Nitroaniline	Acenaphthene	2,4-Dinitrophenol
4-Nitrophenol	Dibenzofuran	2,4-Dinitrotoluene
Diethyl phthalate	4-Chlorophenyl-phenylether	Fluorene
4-Nitroaniline	4,6-Dinitro-2-methylphenol	N-Nitrosodiphenylamine (1)
Benzo(g,h,i)perylene	Hexachlorobenzene	Pentachlorophenol
Phenanthrene	Anthracene	Di-n-butylphthalate
Fluoranthene	Pyrene	Butyl benzyl phthalate
3,3'-Dichlorobenzidine	Benzo(a)anthracene	Chrysene
bis(2-Ethylhexyl)phthalate	Di-n-octylphthalate	Benzo(b)fluoranthene
Benzo(k)fluoranthene	Benzo(a)pyrene	Indeno(1,2,3-cd)pyrene
Dibenzo(a,h)anthracene	4-Bromophenyl-phenylether	

[a]This list is the Semivolatile Target Compound List (TCL) for EPA's Contracts Laboratory Program.

Table 17-5

Summary of Volatile Compounds for Analysis[a]

Chloromethane	Bromomethane	Vinyl chloride
Chloroethane	Methylene chloride	Acetone
Carbon disulfide	1,1-Dichloroethene	1,2-Dichloroethene (total)
1,1-Dichloroethane	Chloroform	1,2-Dichloroethane
2-Butanone	1,1,1-Trichloroethane	Carbon tetrachloride
Vinyl acetate	Bromodichloromethane	1,2-Dichloropropane
cis-1,3-Dichloropropene	Trichloroethene	Dibromochloromethane
1,1,2-Trichloroethane	Benzene	trans-1,3-Dichloropropene
Bromoform	4-Methyl-2-Pentanone	2-Hexanone
Tetrachloroethane	1,1,2,2-Tetrachloroethane	Toluene
Chlorobenzene	Ethyl benzene	Styrene
Xylene (total)		

[a]This list is the Volatile Target Compound List (TCL) for EPA's Contracts Laboratory Program.

Table 17-6

Composition of Red Water Solids

Parameter	Weight Percent
Inorganic Salts	
Na_2SO_3 - Na_2SO_4	32.3
$NaNO_2$	11.2
$NaNO_3$	1.5
SUBTOTAL	55
Nitrobodies	
Sodium sulfate of 2,4,5-TNT	22.7
TNT-sellite complex	16.2
Sodium sulfonate of 2,4,3-TNT	7.6
Sodium sulfonate of 2,3,4-TNT	2.0
2,4,6-TNBA	1.0
White compound sodium salt	1.0
TNBAL	1.0
TNBOH	1.0
Sodium nitroformats	2.5
SUBTOTAL	55.0

Table 17-7

Red Water Elemental Composition

Parameter	Value
Carbon	3 Percent
Hydrogen	0.1 Percent
Oxygen	3.15 Percent
Nitrogen	0.95 Percent
Water	85 Percent
Chlorine	0.00 Percent
Sulfur	0.65 Percent
Ash	7.15 Percent

Table 17-8

Performance Test Operating Conditions

Parameter	Operating Condition[a] Test 1	Test 2
CBC temperature	1,500°F	1,700°F
Combustion chamber pressure	≤ -0.08 in. w.c.	≤ -0.08 in. w.c.
Red water feed rate	1.5 gpm	1.5 gpm
CBC auxiliary fuel flow	180 lb/hr	180 lb/hr
Combustion gas velocity (10 minute rolling average)	3,500 acfm	3,500 acfm

[a] The values given in this table are estimates that may vary during the actual performance test. Test 1 is the low temperature DRE and organic PIC emissions tests. Test 2 is the high temperature metals test.

surrogate waste will be used. The composition of the proposed surrogate waste stream is presented in Table 17-9.

CBC Auxiliary Fuel Flow. Auxiliary fuel will be used as required to maintain the CBC temperature. No permit limits for auxiliary fuel are anticipated.

Combustion Gas Velocity. The target combustion gas velocity is presented in Table 17-8.

POHC, Metals, and Chlorine Feed Rate. The target organic chlorine, POHC, and EPA regulated metals feed rates will be determined during the preparation of the trial burn plan.

Performance Test Results. A performance test report will be prepared and submitted within 90 days of completion of the performance test. The performance test report will address each of the following topics:

- Quantitative analysis of POHCs in the waste feed - The total POHCs in the waste feeds will be calculated and reported for each performance test run.

- Quantitative analysis of POHCs, HCl/Cl_2, metals, and PICs in the exhaust gas - The concentrations and mass emission rates of POHCs, HCl/Cl_2, metals, and PICs in the exhaust gas will be calculated and reported for each performance test run.

- Computation of DRE - DRE will be calculated and reported for each designated POHC based on the total POHC in the waste feeds and the POHC mass emission measured in the stack gas.

- Computation of HCl removal efficiency - HCl removal efficiency, based on the total organic chlorine in the waste feeds and the HCl mass emission measured in the stack gas, will be calculated and reported for each performance test run.

- Computation of particulate emissions - The concentration of particulate in the exhaust gas, corrected to 7 percent O_2, dry basis, will be calculated and reported for each performance test run.

- Identification of fugitive emissions - The performance test report will include a discussion of fugitive emissions observed during the performance test. If

Table 17-9

Surrogate Red Water Composition
(15 percent solids in red water)

Paramater	Weight Percent
3,5-Dinitrobenzoic acid	7.8 Percent
Water	85 Percent
Na_2SO_3	2.6 Percent
Na_2SO_4	2.6 Percent
$NaNO_2$	1.8 Percent
$NaNO_3$	0.2 Percent

fugitive emissions are observed, how the fugitive emissions were brought under control or will be controlled in the future will be discussed.

- Temperatures and combustion gas velocity - The performance test report will include a process parameter summary of the performance test operating conditions, including operating temperatures for the combustion chambers and the stack gas combustion gas velocity.

- CEM measurement of CO, O_2, and THC - CEM measurements of CO, CO_2, O_2, THC, and NO_x concentrations in the stack gas will be provided in the performance test report. Calibration records for the CEM monitors will also be included.

- Other relevant performance test data - The performance test report will include an incineration system process parameters summary and other relevant data required by 40 CFR 264.102 and to demonstrate compliance with performance warranties.

17.5.3.3 Proposed Permit Operating Conditions

The proposed permit operating conditions are presented in Table 17-10. These values may be modified during the detailed design of the CBC or the performance test.

Group A Parameters. The Group A parameters will be continuously monitored and interlocked with the AWFCO. These parameters, except for the ones indicated, will be demonstrated during the performance test and, therefore, will be disconnected during the performance test.

- Minimum CBC Temperature - The proposed minimum CBC temperature is presented in Table 17-10. This value will be the average value demonstrated during Test 1, the low temperature DRE and PIC demonstration tests.

- Maximum CBC Temperature - The proposed maximum CBC temperature is presented in Table 17-10. This value will be the average value demonstrated during Test 2, the high temperature metals emissions test.

- Combustion Chamber Pressure - To prevent fugitive emissions, the CBC will be maintained at a lower pressure than the value listed in Table 17-10. This value is based upon engineering judgement and will not be demonstrated during the performance test.

Table 17-10

Proposed Permit Operating Conditions

Parameter	Operating Condition[a]
Group A Parameters	
Minimum CBC temperature	1,500°F
Maximum CBC temperature	1,700°F
Maximum CBC pressure	-0.08 in. w.c.
Maximum red water feed rate	1.5 gpm
Maximum combustion gas velocity (10-minute rolling average)	3,450 acfm
Maximum stack gas CO concentration (1-hour rolling average, dry basis, corrected to 7% oxygen)	100 ppm
Group B Parameters	
POHC incinerability limits	To Be Determined[b]
Maximum chlorine feed rate	To Be Determined[b]
Maximum antimony feed rate	To Be Determined[b]
Maximum arsenic feed rate	To Be Determined[b]
Maximum barium feed rate	To Be Determined[b]
Maximum beryllium feed rate	To Be Determined[b]
Maximum cadmium feed rate	To Be Determined[b]
Maximum chromium feed rate	To Be Determined[b]
Maximum lead feed rate	To Be Determined[b]
Maximum mercury feed rate	To Be Determined[b]
Maximum silver feed rate	To Be Determined[b]
Maximum thallium feed rate	To Be Determined[b]
Group C Parameters	
Maximum combustion gas temperature after the quench	450°F

[a]The values given in this table are estimates that may vary during the actual trial burn.
[b]To be determined during the preparation of the Trial Burn Plan.

- Red Water Feed Rate - The maximum red water feed rate is presented in Table 17-10 and will be the maximum average value demonstrated during Test 1.

- Combustion Gas Velocity - The proposed maximum combustion gas velocity is presented in Table 17-10. The combustion gas velocity is an indication of residence time in the CBC, which is related to DRE. Therefore, the maximum combustion gas velocity will be the maximum average value demonstrated during Test 1 of the performance test. A 10-minute rolling average is proposed for this value, to prevent spurious AWFCOs.

- Stack Gas CO Concentration - The proposed maximum stack gas CO concentration is presented in Table 17-10. This permit limit will be a 1-hour rolling average, dry basis, and corrected to 7 percent O_2. The maximum stack gas CO concentration will not be demonstrated during the performance test.

Group B Parameters. The Group B parameters will not be continuously monitored and will not be interlocked with the AWFCO system. Operating records will be maintained to demonstrate compliance with these permit limits.

- POHC Incinerability Limits - The POHC incinerability limit will be based on the POHCs selected during the trial burn plan preparation.

- Maximum Chlorine Feed Rate - The maximum feed rate of chlorine will be the average value demonstrated during Test 1, the low temperature DRE and PIC demonstration tests.

- Metals Feed Rate - The maximum feed rate for antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, silver, and thallium will be determined during the preparation of the trial burn plan.

Group C Parameters. The limits on Group C parameters are based on manufacturers' design and operating specifications. Group C parameters do not have to be continuously monitored and do not have to be connected to the AWFCO system.

- Combustion Gas Temperature After the Quench - To protect the equipment after the quench, the maximum gas temperature after the quench will be limited to the value presented in Table 17-10.

17.5.3.4 POHC Selection Rationale

During the preparation the trial burn plan, the POHCs will be selected.

17.5.3.5 Approach to Compliance with Metals Emission Limits

During the preparation of the trial burn plan, the approach to demonstrating compliance with the metals emission limits will be prepared.

17.5.4 Performance Test Organization and Responsibilities

The performance test will be conducted by personnel who are experienced in testing hazardous waste incinerators.

17.5.4.1 Incinerator Project Manager

The incinerator project manager will be responsible for all operational aspects of the test. His responsibilities include:

- Preparing the CBC for the performance test
- Preparing waste feed materials for the performance test
- Operating the CBC at planned test conditions
- Providing all CBC process data as required by the performance test
- Coordinating incinerator operation with the test team activities through communication with the performance test project manager
- Acting as a liaison between the regulatory observers and the performance test manager.

17.5.4.2 Performance Test Project Manager

The performance test project manager will be responsible for implementing and coordinating all aspects of the performance test. His responsibilities during the project will include:

- Implementing the performance test plan
- Implementing the quality assurance project plan (QAPP)

- Preparing and implementing a site H&S plan
- Coordinating incinerator operations and test activities with facility operators and the sampling team
- Monitoring incinerator operations to verify conformance with the performance test objectives.
- Acting as the focal point for communications between the sampling team, CBC operating team, and regulatory observers during the execution of the performance test program
- Deciding when a sampling run will be started, interrupted, or completed.

17.5.4.3 Quality Assurance Officer

The quality assurance officer's responsibilities during the performance test program will include:

- Assisting in preparation and implementation of the QAPP
- Providing independent data review, both operational and analytical
- Making recommendations to the performance test project manager if problems are encountered
- Verifying that appropriate corrective actions are taken if any problems occur
- Reporting, and discussing quality assurance/quality control (QA/QC) activities, data, and results for inclusion in the performance test report.

17.5.4.4 Field Analytical Coordinator

The field analytical coordinator reports to the performance test project manager with lines of communication to the QA officer. The field analytical coordinator's responsibilities will include:

- Preparing and shipping sampling equipment, chemicals reagents, and containers to the test site
- Assigning and recording sample numbers

- Directing and/or participating in sampling activities
- Overseeing sample preservation in the field
- Documenting sampling activities in a field logbook
- Preparing samples for shipment to the laboratory
- Carrying out assigned QA/QC duties
- Preparing a complete sampling report for inclusion in the performance test report.

17.5.4.5 Laboratory Analysis Coordinator

The laboratory analysis coordinator reports to the performance test project manager with lines of communication to the QA officer. His responsibilities will include:

- Coordinating specialized field sampling documentation (request for analysis forms, sample collection sheets, etc.)
- Initiating chain-of-custody records
- Receiving, verifying, and documenting that incoming field samples correspond to the chain-of-custody records
- Maintaining records of incoming samples
- Tracking samples through processing, analysis, and disposal
- Preparing project-specific QC samples for analysis during the project
- Verifying that laboratory QC and analytical procedures are being followed as specified in the QAPP
- Reviewing QC and sample data and determining if additional samples or repeat analyses are needed
- Submitting certified quality control and sample analysis results to the performance test project manager for all analyses requested for this test program
- Archiving storage of analytical data

- Preparing a complete analytical report for inclusion in the performance test final report.

17.5.4.6 Stack Sampling Coordinator

The stack sampling coordinator duties will report to the performance test project manager and have lines of communication to the QA officer. The stack sampling coordinator's responsibilities will include:

- Working with site personnel to obtain sampling locations and platform facilities that are appropriate for the planned stack sampling activities
- Directing stack sampling activities
- Coordinating stack sample beginning and ending times with the performance test project manager
- Notifying the performance test project manager of any interruptions in the sampling activities and recommending corrective actions if necessary
- Recording field test data required by the performance test plan
- Recording and transferring all performance test and QC samples to the laboratory analysis coordinator or his designee
- Preparing a thoroughly documented stack sampling report for inclusion into the final performance test report.

17.6 Air Pollution Control Equipment Operation

A complete description of the APCS equipment operation is presented in Section 2.7. The anticipated operating conditions during routine operation of the CBC are summarized in Table 17-11. The system temperatures, flow rates, and pressure drops will vary over a normal range during routine operation, and these fluctuations are expected to occur during the performance test.

Table 17-11

Air Pollution Control System Operating Ranges

Parameter	Typical Operating Range
Combustion Gas Temperature After Quench	400-450°F
Quench Water Flow Rate	2.0-3.1 gpm
Quench Atomizing Air Flow Rate	100-170 acfm
Combustion Gas Velocity	2,500-3,450 acfm

18.0 BENCH-SCALE TESTING

18.0 Bench-Scale Testing

18.1 Overview and Summary of Key Findings

Red water, a waste stream from the manufacture of TNT, contains between 15 and 30 percent solids, of which about 45 percent are sodium salts and 55 percent are sulfonated derivatives of TNT isomers. It is anticipated that treatment of red water in circulating or fluid-bed combustors will result in a buildup of molten sodium on the bed material. This buildup will have a tendency to cause common bed materials such as silica sand to agglomerate. Molten sodium causes bed particles to agglomerate, which increases the effective particle size and decreases the fluidization and dampening of effectiveness of incineration, resulting ultimately in failure of system.

This document presents the results of an initial treatability study using a surrogate red water solution, to further evaluate this potential problem. Actual red water, which is a RCRA-regulated hazardous waste, was not available for testing. Therefore, a laboratory prepared surrogate, which is not RCRA regulated, was used.

The testing utilized a bench-scale, 4-inch fluid bed system. The tests focused on agglomeration tendencies of two bed materials using surrogate red water was prepared to simulate concentrations of 15 and 30 percent solids. In addition, the test data may be used to evaluate the combustion efficiency and the nitrogen oxide (NO_x) and sulfur oxide (SO_x) levels generated.

The key findings of the tests are that the fluid bed agglomerated at a bed temperature of 745 to 804°C (1373 to 1840°F) irrespective of the bed material; the bed material purge rate was maintained high to minimize salt concentration in the fluid bed; NO_x generation indeed was high primarily due to the salt (sodium nitrate and sodium nitrite) present in the red water, limestone addition to the bed was not required due to the generation of low levels (sulfur dioxide (SO_2); carbon monoxide (CO) and total hydrocarbon (THC) concentrations reduced as the bed temperatures increased; and salt precipitation in the surrogate red water solution was a challenge.

18.2 Test Procedures and Observations

18.2.1 Test Objectives

The objective of these tests was to evaluate bed agglomeration associated with circulating bed incineration of red water. Due to the presence of salts in the red water, a tendency for bed material to agglomerate may exist. Based on the study presented in Chapter 3.0, several materials were evaluated for their use in fluidized beds. These materials include alumina, zircon, clay, limestone, dolomite, gypsum, coal ash, and blast furnace slag. At this time, the two most promising bed materials are alumina and zircon sand with limestone as an additive for acid gas absorption. The test program evaluated agglomeration of sodium salts on these materials.

18.2.2 Waste Characteristics

Because actual red water was not available for testing, a surrogate material was used for the test program. Several surrogate materials such as nitrobenzene, dinitrobenzene, and 3,5-dinitrobenzoic acid were considered as potential candidates. The primary criteria for the selection of the surrogate material are the toxicity of the material itself and the carbon to nitrogen dioxide (NO_2) ($C:NO_2$) ratio to be as close to 2,4,6-TNT, the primary component of the actual red water. 3,5-Dinitrobenzoic acid substituted for the 2,4,6-TNT because this material is the least toxic of all the materials considered and this compound has a $C:NO_2$ ratio of 2.3, which is the same for the 2,4,6-TNT. The components that were used to prepare the surrogate red water are listed in Table 18-1. The anticipated elemental composition of the surrogate red water is presented in Table 18-2. The average heating value of the red water and for the surrogate red water is 487 Btu/lb and 479 Btu/lb, respectively.

A sufficient quantity of surrogate red water was prepared to allow 2 days of testing (8 hours/day) at a feed rate of approximately 1.0 liter/hour. Two tests were conducted using surrogate red water with 15 percent solids, and two tests were to be conducted using surrogate red water with 30 percent solids. The 15 percent solids test case is the design basis for the pilot-scale unit and the 30 percent solids test case is the worst-case concentration from a salt concentration and thermal input view point.

Table 18-1

Anticipated Composition of Two Surrogate Red Water Matrices

Component	Solids Concentration[a]	
	15% Solids Matrix	30% Solids Matrix
Water	85	70
3,5-Dinitrobenzoic acid	7.8	15.7
Sodium Sulfite	2.6	5.1
Sodium Sulfate	2.6	5.1
Sodium Nitrite	1.8	3.6
Sodium Nitrate	0.2	0.5
Total	100	100

[a]Percent by weight.

Table 18-2

Anticipated Elemental Composition of the 15% and 30% Solids Surrogate Red Water Matrix

	3,5-Dinitrobenzoic Acid	Water	Na_2SO_3	Na_2SO_4	$NaNO_2$	$NaNO_3$	Surrogate Mixture
%C	39.63	0.00	0.00	0.00	0.00	0.00	3.12
% H_2	1.90	0.00	0.00	0.00	0.00	0.00	0.15
% 0_2	45.26	0.00	0.00	0.00	0.00	0.00	3.56
% N_2	13.21	0.00	0.00	0.00	0.00	0.0	1.04
% Water	0.00	100.00	0.00	0.00	0.00	0.00	85.00
% CL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% BR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% P	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% SALT	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ash	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Inert	0.00	0.00	100.00	100.00	100.00	100.00	7.14
Total	100	100	100	100	100	100	100
lb/hr	65.0	702.1	21.1	21.1	14.7	2.0	826
Btu/lb	6,084.4	0.0	0.0	0.0	0.0	0.0	478.5
Surrogate Weight (%)*	7.86	85	2.6	2.6	1.78	0.24	100
Surrogate Weight (%)**	15.73	70	5.1	5.1	3.6	0.5	100

Assumptions:

3,5-Dinitrobenzoic acid is spiked to provide the NO_2 in the surrogate mixture.
* - 15 percent solid content in the surrogate mixture
** - 30 percent solid content in the surrogate mixture

Of the 15 percent solids, sodium salts accounted for 7.2 percent and the balance of 7.8 percent was the surrogate compound, 3,5-dinitrobenzoic acid. Initially, a salt solution was prepared by dissolving known quantities of salts (refer to Tables 18-1 and 18-2 of test plan) in water.

When the dinitrobenzoic acid was slowly added to the salt solution, in a stirred container, brownish colored fumes were generated. The brownish colored fumes are due to the formation of NO_2 due to the following reaction:

$$NO_3^- + e^- \rightarrow NO_2 \uparrow (brown) + H_2O$$

To avoid fuming, dinitrobenzoic acid was neutralized externally by one normal caustic solution and the resultant solution was mixed with the salt solution. Neutralization of the benzoic acid solution prior to its blending with the salt solution produced the reaction below as evidenced by the lack of brown fumes:

$$R\text{-}COOH + NaOH \rightarrow R\text{-}COO^- \; Na^+ + H_2O$$

Although fuming was avoided, some undissolved salts precipitated at the bottom of the feed container. As the testing continued, the feed solution changed its color (from deep red to brown) upon exposure to ambient air and more salt precipitation occurred. Due to the challenges discussed above, a solution containing 30 percent dissolved solids was not prepared.

Red water is thought to derive its color from sulfonate adducts of the various trinitrotoluene isomers that are formed when sodium sulfite is added to the TNT during the purification processes. The sulfite reacts with the isomers of TNT (but not 2,4,6-TNT) and forms the sulfonate adducts that are easily separated from the process during product crystallization. The sulfonate compounds are sufficiently soluble to allow separation of them from 2,4,6-TNT with washings. Solutions of these washings are the sodium salts of the organic sulfonates and are characteristically red in color. This same red color is observed in the surrogate red water mixture used in the test. The color is apparently due to the formation of benzoic acid sulfonate. However, the red color formed initially upon mixing the components of the red water surrogate slowly degrades to a brown colored solution. The disappearance of the

characteristic red color indicates that the nitrosulfonate derivative has probably further reacted to form a sulfone and can probably be abated with the use of an elevated pH;

$$R\text{-}SO_3^- - Na^+ \rightarrow R\text{-}SO_2 \downarrow (brown\ or\ yellow) + NaOH$$

This reaction scheme should be regarded as tentative, but will be useful in the continuing consideration of the testing of this mixture as an appropriate surrogate for red water.

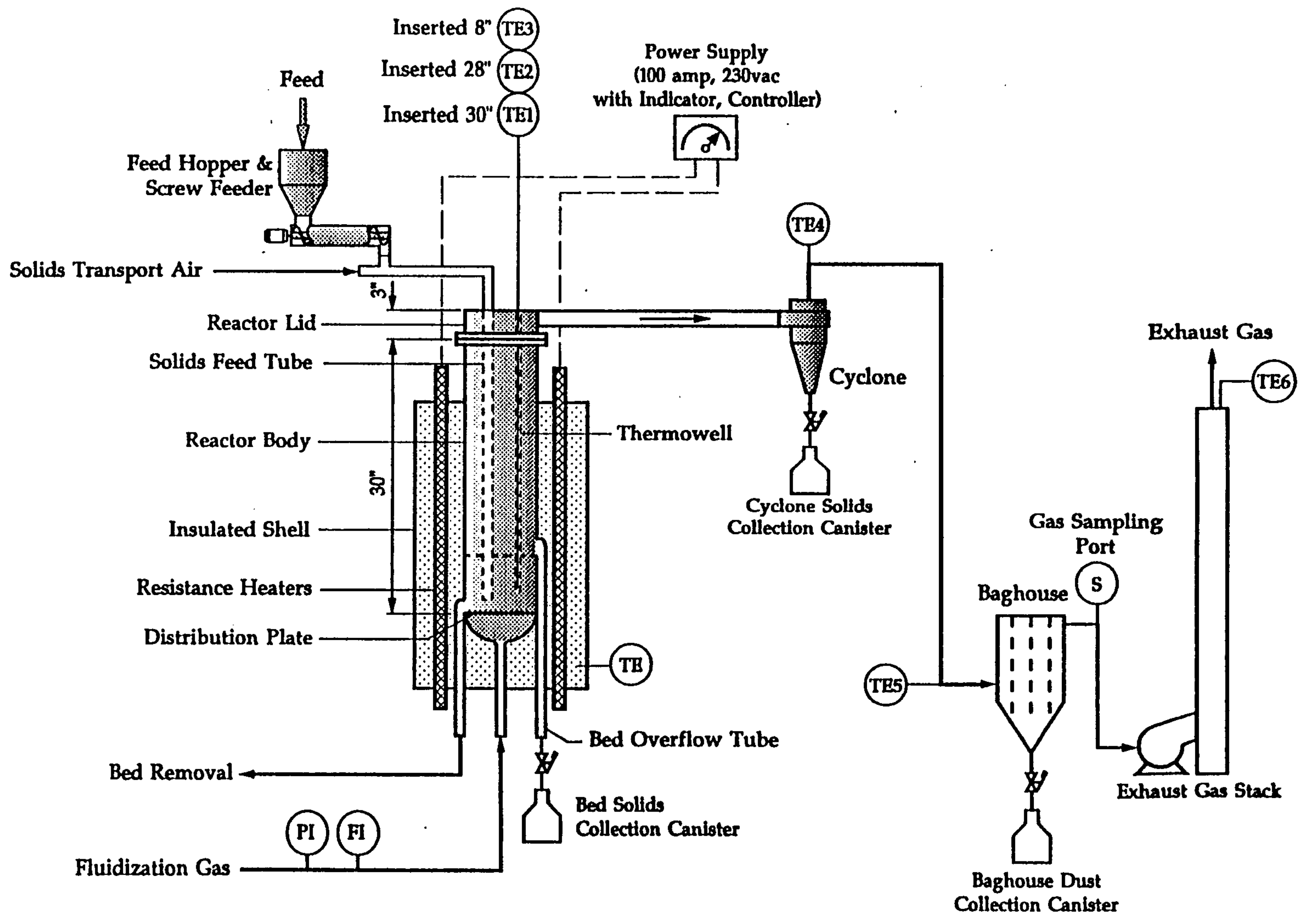
Because the presence of undissolved salts in the feed solution caused plugging problems in the feed tubing and increased agglomeration potential during testing, it is recommended that the actual red water containing no suspended salts be used during pilot-scale testing.

18.2.3 Test Equipment

The test unit (Drawing No. D-00-00-03) was a 4-inch-diameter, bench-scale, fluid-bed reactor which approximately simulates a CBC. The tests were conducted at Hazen Research facility at Golden, Colorado on February 22 and 23, 1995. The bench-scale combustor was an existing unit that has been used in several similar research efforts. This fluid bed combustor has been shown to be a reasonable simulation of a CBC unit. The exhaust gas passed through a cyclone and a bag house for particulate collection and into a caustic scrubber for acid gas capture. A slip stream of the exhaust gas was sent to a CEM unit for analysis of gas composition. Concentrations of O_2, CO_2, CO, SO_x, NO_x, and THC were measured by the CEM.

18.2.4 Feed/Ash/Stack Gas Sampling and Analysis Plan

The surrogate red water was prepared using commercial-grade materials per the recipe presented in Table 18-1. Bed overflow (ash) samples were collected for particle size distribution and sodium analyses. The bed material from each test was sampled and analyzed for mineralogy. The sample analysis and analysis procedures for the tests are presented in Table 18-3. The stack gas was analyzed for O_2, CO_2, CO, NO_x, SO_x, and THCs. Based on discussions in Chapter 3.0, NO_x emissions may be high due to the conversion of "nitro" molecules into NO_x. During the testing, the stack gas was observed for visible (brown to red color) NO_x emissions. Table 18-4 presents the model numbers and ranges for the CEM analyzers.



Drawing No. D-00-00-03 4-Inch Fluid Bed Reactor System

Table 18-3

Sample Analysis Procedures

Sample Matrix	Determination	Procedure
Surrogate Red Water	Elemental Composition	Mathematical Calculation[a]
Fluid Bed Overflow Material	Particle Size Distribution	Sieve Screen Analysis
Fluid Bed Overflow Material	Sodium Content	Flame Atomic Absorption
Final Bed Material	Mineralogy	X-Ray Deffraction
Offgas	O_2, CO_2, CO SO_2 NOx THC	EPA Method 3A EPA Method 6C EPA Method 7E EPA Method 25A

[a]Note: The surrogate composition was calculated based on the recipe used for formulation.

Table 18-4

Model Numbers and Ranges of Continuous Emissions Monitors

Parameter	Model Number	Range (%) [ppm]
Oxygen	Infrared Industries Model 2000	0 to 1 0 to 10 0 to 25
Carbon Dioxide	Infrared Industries	0 to 20 0 to 100
Carbon Monoxide	Beckman Model 864	[0 to 500] [0 to 5,000]
Sulfur Dioxide	Thermo Electron Pulsed Fluorescence Model 40	[0 to 50] [0 to 100] [0 to 500] [0 to 1,000] [0 to 5,000]
Nitrogen Oxides	Beckman Model 951A	[0 to 10] [0 to 25] [0 to 100] [0 to 250] [0 to 1,000] [0 to 2,500] [0 to 10,000]
Total Hydrocarbon	Thermo Environmental	[0 to 100] [0 to 1,000] [0 to 10,000]

18.2.5 Test Plan and Test Discussion

The tests were conducted at a solids concentration of 15 percent on each of the two selected bed materials. Aluminum oxide and zircon silicate were used as primary bed materials.

After some initial testing, it was evident that the fluid bed incinerator could not be operated at 870°C (1600°F) due to bed material agglomeration. The SO_2 generation was so low that the lime injection to the bed became unnecessary.

During the first day of tests, all the tests were conducted using zirconia sand as the bed material. Base Case 1 (Table 18-5) was conducted at a bed temperature of 645°C (1193°F) using salt solution alone. Base Case 2 was conducted at test conditions same as in Base Case 1, except surrogate solution was used. The NO_x concentration for these cases were about the same while the CO, THC, and CO_2 concentrations were higher for Base Case 2 due to the combustion of the surrogate compound. The remaining tests were conducted using surrogate solution at increasing bed temperatures. the system operated well at bed temperature of 692°C (1278°F) and 745°C (1373°F). During these testings, the bed purge rate was maintained approximately the same as the bed feed rate to maintain a low salt concentration in the bed. The test results for the aforementioned tests are presented in Table 18-5.

During the second day of tests, the tests were repeated using alumina as the bed material. The results were similar to ones with zirconia sand as the bed material. Defluidization did not occur even at a bed temperature of 804°C (1480°F). The CO and THC concentrations were lower for alumina compared with zirconia sand as the bed material. Because alumina is lighter than zirconia sand, more bed material entrained causing better mixing of the solids with gases improving combustion conditions. The test results for these tests are presented in Table 18-6.

18.3 Summary of the Test Results and Potential Impact on Conceptual Pilot-Plant Design

18.3.1 Mass Balance Across the System

The objective of the mass balance applied on the fluid bed was to reproduce test conditions and ascertain the accuracy of the test data. In addition, the mass balance allows the calcula-

Table 18-5

Summary of Bench-Scale Fluid Bed Testing (Zirconia sand as bed material) Testing on February 22, 1995

Bed Material	Test Number	Feed Material	Feed Rate (g/min)	Bed Temp. (°C)	Test Time (hrs.)	Bed Feed Rate (g/min)	Bed Product (g/min)	Gas Composition					
								NO_x (ppm[d])	SO_2 (ppm[d])	CO (ppm[d])	THC (ppm[w])	O_2 (%)	CO_2 (%)
Zirconia Sand	Base Case 1	Salt Only	8.0	645	1.5	51.0	51.7	1840	3	6	0	20.5	0.0
Zirconia Sand	Base Case 2	Surrogate	8.6	652	1.5	53.0	53.3*	1768	3	464	5	19.8	0.9
Zirconia Sand	Test 1	Surrogate	9.0	692	1.0	51.9	51.3	1773	3	407	0	19.7	1.0
Zirconia Sand	Test 2	Surrogate	8.9	745	0.5	54.7	34.2	2040	3	258	0	19.7	1.0
Zirconia Sand	Test 3	Surrogate	8.4	772	0.5	-	-	-	Defluidization Occurred			-	-
Average Value[a]			8.8			53.2	46.2	1860	3	376	1.7	19.7	1.0

Notes: *visible carbon in ash, surrogate - 15% dissolved solids, no limestone added to the fluid-bed incinerator.
[a]Average of Base Case 2, Test 1 and Test 2 values.

Table 18-6

Summary of Bench-Scale Fluid Bed Testing (Alumina as bed material) Testing on February 23, 1995

Bed Material	Test Number	Feed Material	Feed Rate (g/min)	Bed Temp., (°C)	Test Time, (hrs.)	Bed Feed Rate, (g/min)	Bed Product (g/min)	Gas Composition					
								NO_x (ppm[d])	SO_2 (ppm[d])	CO (ppm[d])	THC (ppm[w])	O_2 (%)	CO_2 (%)
Alumina	Base Case 1	Salt Only	8.7	645	1.5	36.3	33.4	1746	2	6	0	20.5	0.0
Alumina	Base Case 2	Surrogate	7.5	650	1.5	40.3	33.2**	1500	2	290	1	19.9	0.8
Alumina	Test 1	Surrogate	8.9	697	1.0	43.0	38.5	1894	2	347	1	19.7	1.0
Alumina	Test 2	Surrogate	7.7	745	0.9	43.5	58.0	1633	2	189	0	19.9	0.7
Alumina	Test 3	Surrogate	7.9	804	0.6	47.6	48.3	1626	2	25	0	20.0	0.8
Average Value[b]			8.1			42.2	42.3	1680	2	171	0.4	20.0	0.7

Notes: **No carbon visible in ash, surrogate with 15 percent dissolved solids used; no limestone added to the incinerator.
[b]Average of Base Case 2, Test 1, 2 and 3 values.

tion of nonmeasured values, i.e., percent particle entrained in the combustion off-gas. Mass balance values for the steady-state operation are presented in Table 18-7. The operational data presented in Tables 18-5 and 18-6 were used in the mass balance. Among other parameters, the input of surrogate red water solution feed rate and composition, fluidization air rate were the starting point of the mass balance.

The feed rates and the composition were used in the mass balance, and CEM values such as NO_x, SO_2, CO, CO_2, and O_2 were duplicated. Based on the values presented in Table 18-7, the calculated values agreed very closely with the CEM-measured values indicating a good mass balance closure for a short test. With a good mass balance, the values discussed in this report are considered reliable.

18.3.2 Bed Agglomeration and Bed Material Purge

Defluidization due to bed material agglomeration occurred for zirconia sand at a bed temperature of 772°C (1420°F) and for alumina at a bed temperature of greater than 804°C (1480°F), respectively. The premature agglomeration of the fluid bed was primarily due to the low melting point of salts. These molten salts provided a glue for the bed material particles to stick together forming balls of bed material causing defluidization. The agglomeration potential greatly increased due to the precipitation of additional salt in the surrogate red water solution upon its exposure to the ambient air. This observation was made during the 2-day testing.

The actual red water does not contain suspended salt particles. Therefore, it is recommended that the actual red water instead of surrogate red water solution be used during the pilot-scale testing to minimize agglomeration potential. Also, even if the balls of bed material are formed, a full-scale CBC will provide greater opportunity for additional break up of large agglomerates compared to a bench-scale fluid bed incinerator.

The bed material purge rate was maintained approximately equal to the bed material feed rate to maintain a low (1 percent) salt concentration in the fluid bed to minimize agglomeration potential. This mode of operation may be uneconomical unless the purged solids are processed to remove salts and then recycled.

Table 18-7

Summary of Surrogate Redwater Test Results

Parameter (measured/calculated)	w/Zirconia Sand					w/Alumina					
	Base Case 1	Base Case 2	Test 1	Test 2	Average*	Base** Case 1	Base Case 2	Test 1	Test 2	Test 3	Average*
Theoretical Oxygen Demand (g/min)	0.00	0.50	0.52	0.52	0.51	0.00	0.44	0.52	0.45	0.46	0.47
Percent Combustion Efficiency (percent)	100.0	95.6	96.6	97.8	96.7	100.0	96.9	97.1	98.2	99.7	98.0
Percent Organic N_2 to NO_x	0.0	19.6	13.0	21.5	18.0	0.0	17.9	17.2	16.9	26.0	19.5
Percent Oxidation	100.0	99.6	100.0	100.0	100	100.0	99.9	100.0	100.0	100.0	100
Combustion Air Flow (g/min)	76.09	58.70	54.35	54.35	55.80	82.61	58.70	54.35	54.35	65.22	58.15
Percent Inorganic SO2 to Off-Gas	0.25	0.20	0.20	0.20	0.20	0.20	0.15	0.14	0.14	0.14	0.14
Percent of Bed Material Entrained in Off-Gas	0.00	0.55	2.40	38.50	13.82	9.50	18.80	11.90	0.00	0.00	7.7
Percent Salts Entrained in Off-Gas	0	0	0	0	0	0	0	0	0	0	0
CEM O_2 (% dry volume) Calculated O_2 (% dry volume)	20.5 20.7	19.8 19.8	19.7 19.7	19.7 19.7	19.7 19.8	20.5 20.7	19.9 19.9	19.7 19.7	19.9 19.9	20.0 20.0	19.9 19.9
CEM CO_2 (% dry volume) Calculated CO_2 (% dry volume)	0.0 0.0	0.9 1.0	1.0 1.2	1.0 1.2	1.0 1.1	0.0 0.0	0.8 0.9	1.0 1.2	0.7 1.0	0.8 0.9	0.8 1.0
CEM NO_x (ppm dry volume) Calculated NO_x (ppm dry volume)	1,840 934	1,768 1,768	1,773 1,773	2,040 2,040	1,860 1,860	1,746 936	1,500 1,500	1,894 1,894	1,633 1,633	1,626 1,626	1,663 1,663
CEM SO_2 (ppm dry volume) Calculated SO_2 (ppm dry volume)	3 3	3 3	3 3	3 3	3 3	2 2	2 2	2 2	2 2	2 2	2 2
CEM CO (ppm dry volume) Calculated CO (ppm dry volume)	6 0	464 464	407 408	258 258	376 377	6 0	290 290	347 346	189 189	25 25	213 212
CEM THC (ppm wet volume) Calculated THC (ppm wet volume)	0 0	5 5	0 0	0 0	2 2	0 0	1 1	1 1	0 0	0 0	1 1

Notes:

*The average does not include Base Case 1.
**Base Case 1 contains Salt Solution only.
CEM - Continuous Emission Monitoring.

If the circulating bed operating temperature cannot be increased greater than 1480°F to avoid agglomeration of the bed, the solids and gas residence time in the CBC may have to be increased to more than 2 seconds to meet the DRE requirement of 99.99 for the surrogate material.

18.3.3 NO_x Generation

The two sources of NO_x during the tests were a) thermal decomposition of $NaNO_2$ $NaNO_3$ and b) organic N_2 present in the surrogate red water solution. The NO_x formation was approximately the same when salt solution alone and surrogate solutions were incinerated. This result indicates that primarily the Na salts thermally decomposed to NO_x and molten sodium while a fraction of 18 to 19.5 percent of the organic-nitrogen converted to NO_x. based on the test results, the emission of NO_x for the pilot unit will be 69 tons per year (refer to attached calculations), which is well below the 250 tons per year PSD limit for new sources; however, the limit is site-specific.

18.3.4 SO_2 Generation

Because the surrogate red water and bed material did not contain any elemental S, SO_2 generation was due to the thermal decomposition of Na salts. At the incineration temperatures, during testing, NA sulfites and Na sulfates did not decompose to SO_2 significantly. The SO_2 formation was in the range of 2 to 3 parts per million (ppm), and therefore, limestone as an additive for acid gas absorption was not injected to the incinerator during testing. Based on the test results, the emission of SO_2 for the pilot unit will be 62 tons per year (refer to attached calculations).

18.3.5 CO, CO_2, and THC Concentrations in the Incinerator Off-Gases

The only source of carbon in the surrogate red water solution was 3,5-dinitrobenzoic acid, the surrogate compound; no other feed material introduced to the fluid bed contained carbon source. The measured THC value and the presence of carbon in the bed and cyclone product (B&CP) indicate incomplete combustion of the carbon in the surrogate compound. For all the tests, the combustion efficiency was in the range of 98 to 99 percent. The presence of fixed carbon in the B&CP may be due to the presence of molten sodium in the B&CP; localized pockets or balls of bed material coated with molten sodium may have produced inadequate

mixing in the fluid bed. Additionally, the absence of the dynamics of a very well mixed bed as present in a full-scale CBC also contributes to inefficient combustion.

18.4 Conclusions

The following conclusions were drawn based on the bench-scale fluid bed incineration testing using the surrogate red water:

- Defluidization occurred due to agglomeration at a fluid bed temperature of 645 to 804°C using zirconia sand and alumina as bed materials. The premature agglomeration of the fluid bed was primarily due to the melting of the low melting salts in the feed solution. Therefore, the importance of the bed material was not realized in the tests. An average salt concentration of less than 1 percent should be maintained in the purged solids to avoid agglomeration.

- Actual red water containing minimal to none salts precipitate be used instead of surrogate red water solution for the CBC pilot tests.

- NO_x generation was primarily due to the thermal decomposition of Na nitrites and nitrates while a small fraction of NO_x was formed due to the surrogate compound. Based on the test results, the estimated emission of NO_x for the pilot unit is 69 tons per year, which is well below the 250 tons per year PSD limit for new sources, but the limit is site specific. Percent organic N_2 converted to NO_x was in the range of 18 to 19.5 percent.

- SO_2 formation was minimal at 2 to 3 ppm. At the incineration temperatures tested, Na sulfites and Na sulphates did not decompose into SO_2 significantly. Limestone injection as an additive for acid gas absorption was not required during testing. Based on the test results, the estimated emission of the SO_2 for the pilot unit will be 62 tons per year.

- Despite the poor mixing of the bed solids and the incinerator off-gases due to agglomeration, the combustion efficiency for all the tests were in the range of 98 to 99 percent.

OBJECTIVE:

Determine NO_x emission from CBC based Redwater Surrogate Test.

REFERENCE:

(1) Calculation Set #1 Pages 1 of 1 4/3/95
(2) Redwater Surrogate Test.

METHODOLOGY:

NO_x emission in CBC is from three sources: (a) Thermal NO_x, (b) Organic nitrogen in the waste, and (c) In-Organic nitrogen.

(a) Thermal NO_x = $\boxed{0.38 \text{ lb/hr}}$ (Set #1 Page 1 of 1)

(c) ($NaNO_3$) & ($NaNO_3$) = 9.26 + 1.01 = $\boxed{10.27 \text{ lb/hr}}$

(b) Organic nitrogen in the waste. % nitrogen in redwater = 0.95 %

Redwater feedrate to CBC = 826. lb/hr
Organic Nitrogen Feedrate = 826 lb/hr * 0.95% = 7.85 lb/hr

Maximum NO_x is when 100% of organic nitrogen is converted to NO_x. However, the redwater test demonstrated that 19.5% Conversion of $N_2 + O_2 \longrightarrow NO_2$

$$NO_x \text{ emission} = \frac{7.85 \text{ lb } N_2}{\text{hr}} \; \frac{2 \times 46}{28} \; * \; \frac{19.5}{100} = \boxed{5.03 \text{ lb/hr}}$$

Total NO_x = 0.38 lb/hr + 10.27 lb/hr + 5.03 lb/hr = $\boxed{15.68 \text{ lb/hr}}$

Annual NO_x emission = 15.68 lb/hr * 8760 hr/yr = 137,353. lb/yr = $\boxed{69.0 \text{ Ton/Yr}}$

OBJECTIVE:

Determine SO_2 emission from the incineration of redwater, based on Surrogate Redwater Test.

REFERENCE(S):

- SO_2 Emission from CBC by SKZ 9/22/94 Set#3
- Surrogate Redwater Test.

Methodology:

(A)
- SO_2 emission is formed from 2 sources, organic & in-organic sulfur.
- SO_2 from organic sulfur = $\boxed{10.719 \text{ lb/hr}}$
- SO_2 from in-organic sulfur = $\frac{18.05 \text{ lb}}{\text{hr}} * 0.2\% = \boxed{3.61 \text{ lb/hr}}$

Total SO_2 formed = $10.719 \text{ lb/hr} + 3.61 \text{ lb/hr} = \boxed{14.33 \text{ lb/hr}}$

$$@ = \frac{14.33 \text{ lb}}{\text{hr}} \; \frac{\text{lbmole}}{64 \text{ lb}} \; \frac{\text{hr}}{136.7 \text{ lbmole}} = \boxed{1638 \text{ ppm dry}}$$

the above is for 15% Solids in Redwater

(B) SO_2 emission for 30% Solids

$$SO_2 \text{ emission} = 14.33 \text{ lb/hr} * \frac{30\% \text{ Solids}}{15\% \text{ Solids}} = \boxed{28.7 \text{ lb/hr}}$$

@ 3,276 ppm dry std.

INTERNATIONAL TECHNOLOGY CORPORATION

By SKZ Date 4/3/1995 Subject USAEC - CBC Sheet No. 2 of 2

Chkd. By ___ Date ___ Lime Consumption Proj. No. 322243

Lime Consumption

From Set #3 Page 3 of 3, by: SKZ 9/22/95

For lime Nuetralization CaO to SO_2 Ratio = 0.88 $\frac{lb\ CaO}{lb\ SO_2}$

Normal lime consumption = $14.33 \frac{lb\ SO_2}{hr} * 0.88 \frac{lb\ CaO}{lb\ SO_2} = \boxed{12.6\ lb/hr}$

19.0 HAZOP ANALYSIS

19.0 HAZOP Analysis

Introduction

A hazard and operability study (HAZOP) was conducted of the proposed circulating bed combustor pilot facility to be initially installed at the RAAP facility in Radford, Virginia. The study was based on information depicted on process flow diagram D-00-10-001 REV.A and preliminary process and instrument drawings (P&IDs) D-20-11-001,002 REV. A and D-50-11-001 REV. A. Additional information in this conceptual design report pertaining to the process operating procedures and controls were reviewed and used to develop recommendations for the study. Material and chemical hazards from red water and other feeds and byproducts were evaluated based on material safety data sheet information for 2,4,6-trinitrotoluene, sodium nitrite and sodium nitrate salt solutions, and aluminum oxide.

Methodology

A conventional HAZOP technique was used to identify potential modes of failure, describe the consequences of these failures, and determine existing design safeguards to prevent or mitigate the consequences. Additional safeguards are proposed where potential failures have a relatively likely chance to occur and few existing safeguards are present. These proposed recommendations are listed as action items in Table 19-1 of this report. Immediately following the action table, Table 19-2 is a detailed listing of the potential failure modes (such as high temperature) and potential consequences (i.e., damage to refractory) for each flow stream of the system. Safeguards, such as high temperature alarms that are interlocked to shut down the system, are listed in Table 19-2 for each failure mode.

Study Recommendations

There are 40 recommendations to eliminate or mitigate the consequences of potential failures due to control system failures, wear and tear, human error, malfunctioning equipment, and natural events such as freezing weather. Control system failures amounted to 24 recommendations to consider providing additional monitoring of control parameters for system temperatures, flows, bed depth, and pH control. Maintenance items accounted for nine recommendations to consider programs and procedures to inspect for leaks, develop added emergency plans and regulate operations of heavy equipment. Equipment failures accounted for three

Table 19-1

HAZOP Analysis Recommendations

(Page 1 of 3)

Reference Number	Priority	Action	Responsibility	Status
001		Consider adding low temperature alarm to TIT-206A&B (Item 1.1)	IT	TSL-206 and TAL-206 to be added to alarm on low temperature
002		Check consequence of auxiliary fuel increase to keep up with drop in temperature. Consider adding maximum flow rate alarm (Item 1.1)	IT	FSL-205 and FAL-205 add to alarm on high flow
003		Consider adding procedure to lock open block valves except for maintenance (Item 1.2)	IT/USAEC	
004		Consider adding low flow alarm to FE-205 (Item 1.2)	IT	Alarms sufficient to determine source of malfunction
005		Consider use of 316 stainless steel piping (Item 1.4)	IT/USAEC	
006		Consider heat trace for this line (Item 1.5)	IT/USAEC	
007		Consider procedure to test feed stream composition (Item 1.8)	IT/USAEC	
008		Consider active inspection program and preventive maintenance of feed lines (Item 1.9)	IT/USAEC	
009		Consider specifying drip pans for drain valve (Item 1.9)	IT/USAEC	
010		Consider restricting heavy equipment from areas near pipeline (Item 1.10)	IT/USAEC	
011		Consider adding redundant level controls for bed (Item 2.1)	IT	No action. Current controls indicate bed condition
012		Consider adding controls to allow CCS operator to regulate feed rates of bed materials and limestone (Item 2.1)	IT	Operator to adjust during shakedown and start-up
013		Consider speed alarm for motor on H-2005 (Item 2.2) See 2.1 (Item 2.3)	IT	No action. Alarm will not identify all sources of malfunction

Table 19-1

(Page 2 of 3)

Reference Number	Priority	Action	Responsibility	Status
014		Consider regular inspection and preventive maintenance program (Item 2.8) See 1.8 (Item 2.9) See 2.1 (Item 2.10)	IT/USAEC	
015		Consider adding speed control monitor for H-2001 in CCS (Item 2.10) See 2.1 and 2.2 (Item 2.11)	IT	Same as 013
016		Consider pH monitoring for acid gases (Item 2.14)	IT/USAEC	HCl monitoring should be considered
017		Consider monitoring of salt in ash variation with flow (Item 2.14)	IT/USAEC	
018		Consider check of gas supply quality (Item 3.5)	IT/USAEC	
019		Consider specifying filter for natural gas supply (Item 3.8)	IT/USAEC	
020		Consider developing preventive maintenance procedure (Item 3.9) See 1.10 (Item 3.10)	IT/USAEC	
021		Consider regular maintenance procedure for filter (Item 5.8)	IT/USAEC	
022		Consider review of control method for this stream (Item 6.1)	IT	Change signal source to TY-206. Add explanatory note
023		Consider review of control method for this stream (Item 6.2)	IT	See 022
024		Consider CCS indication of speed control for H-2001 (Item 7.1) See 2.1 (Item 7.2)	IT	Add temperature alarm. See 025
025		Consider temperature sensor on H-2001 body or water jacket (Item 7.4)	IT	Add high temperature alarm to TIT-210
026		Consider special procedures for handling ash to avoid worker exposure (Item 7.8)	IT/USAEC	

Table 19-1

(Page 3 of 3)

Reference Number	Priority	Action	Responsibility	Status
027		Consider regular inspections and preventive maintenance of conveyor housing (Item 7.9) See 2.8 (Item 8.9)	IT/USAEC	
028		Consider adding TSLL-501 (Item 9.1)	IT	Add TAL-501 to alarm on low temperature
029		Consider adding FAH-501 (Item 9.1)	IT	Low temperature alarm sufficient
030		Consider making TV-501 fail closed (Item 9.1)	IT	Make TV-501 fail open
031		Consider heat tracing this line (Item 9.3) See 1.10 (Item 9.10)	IT/USAEC	
032		Consider monitoring pH of acid gas (Item 11.9) See 1.9 (Item 11.10)	IT	Same as 016
033		Consider inspection of bags for premature wear (Item 12.6)	IT/USAEC	
034		Check on specification for air dryer; consider moisture alarm on air system (Item 12.8)	IT	Cover in specification for air drying system
035		Consider review of emergency fire safety equipment and procedures (Item 13.4)	IT/USAEC	
036		consider redundant flow indication (Item 15.1)	IT	Not recommended practice. High flow not a deficiency
037		Consider low flow alarm (Item 15.2) See 15.2 (Item 15.7)	IT	Differential pressure measurement in bed is sufficient
038		Consider pH monitoring for acid gases (Item 15.8)	IT	Same as 016
039		Consider speed control monitor (Item 17.1)	IT	Same as 013
040		Consider monitoring pH in ash (Item 17.2)	IT/USAEC	See 017

Table 19-2

HAZOP Analysis

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
1.0 Line - Red Water Feed (Drawing: D-20-11-001)					
1.1	High flow	Supply source produces high output FY-205 high output FE-205 fails low or low output FIT-205 fails low or low output	High flow of red water resulting in lower heat release Reduced treatment effectiveness	Flow control valve FV-205 regulates flow TALL-206 alarms and shuts off flow AI-502 alarms on high CO	001
1.2	Low/no flow	FV-205 fails closed YV-fails closed Low source output Block valve inadvertently left closed FE-205 high output FIT-205 high output FY-205 low output	TAHH-206 alarms on high temperature High temperature in combustor Potential slagging Potential refractory damage	ZLL-205 alarms on closure of FV-205 ZLL-205A alarms on closure of YV-205 Flow control valve FV-205 regulates flow	003 004
1.3	Reverse/misdirected flow	No credible cause (NCC)			
1.4	High temperature High flow of solids in feed	High ambient temperature	High corrosivity at temperatures oer 100 degrees F	None	005
1.5	Low temperature	Freezing water	Pipe rupture and red water release; potential for dry feed to explode	None	006
1.6	High pressure	Block valve inadvertently closed FV-250 or YV-205 fails closed	See 1.1	See 1.1	
1.7	Low pressure	See 1.2	See 1.2		

Table 19-2

(Page 2 of 16)

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
1.0 Line - Red Water Feed (Drawing: D-20-11-001) (Continued)					
1.8	High concentration of contaminants	Feed source concentration of solids out of specified limits	Higher corrosivity of feed stream	None	007
1.9	Leak	High corrosive wear of pipe Loose fitting Sample drain valve left open	Exposure of maintenance workers to toxic material Potential for dry feed material to explode	None	008 009
1.10	Rupture	Impact by operations or maintenance heavy equipment	See 1.9	None	010
2.0 Heater - Circulation Bed Combustor (Drawing: D-20-11-002)					
2.1	High flow	See 1.1 High flow in purge gas (see 16.1) Low flow of bed material High flow of combustion air (see 6.1)	See 1.1 Potential carryover of particulate Bed depths falls low Potential for erosion of refractory	See 1.1 PDI-206 alarms high Flow rate in stack alarms high	011 012
2.2	Low/no flow	Blockage in bed material in feed chute Failure of motor on H-2005 Low flow of purge gas (see 16.2)	Excess liquid in combustor; potential dousing of burner flame Low fluidization of bed	PDI-206 alarms on low differential pressure	013
2.3	Reverse/misdirected flow	Loss of bed material feed	Loss of bed depth; reverse flow through CBC	PDI-206 alarms on low differential pressure	
2.4	High temperature	Low flow of combustion material (see 1.1) High fuel flow (see 3.1 and 4.1) TY-206 low output TIC-206 fails low	Damage to refractory High off-gas temperature; fire in baghouse Slagging	TE-209 alarms high TE-206A & B alarms high TI-207A & B alarm high	

Table 19-2

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
2.0 Heater - Circulation Bed Combustor (Drawing: D-20-11-002) (Continued)					
2.5	Low temperature	TY-206 high output Low fuel flow (see 3.2 and 4.2) High flow red water feed	Incomplete combustion	AI-502 alarms high CO reading	
2.6	High pressure	Blockage in feed duct High pressure purge gas (see 16.6) PIC-210 fails low PV-510 fails closed High secondary air flow (see 6.1)	Failure of feed and circulation Excess carryover of particulate	PIT-210 alarms high PDI-206 alarms high or low PIC-210 controls ID fan inlet pressure and system pressure	
2.7	Low pressure	Blockage in feed duct Low pressure in purge gas (see 16.7) Low secondary combination air flow	See 2.2	See 2.2	
2.8	Leak	Corrosive action of feed material Erosive action of bed material Loose fitting	In leakage of air; small reduction in temperature	None	014
2.9	Rupture	Over pressure due to high concentration of solids in red water feed materials	Release of off-gas to the atmosphere	None	See 007
2.10	High level	H-2004 high speed H-2001 failure low flow	Bed depth too high	PDI-206 alarms high	015
2.11	Low level	H-2005 failure H-2001 high pressure	Low fluidization of bed	PDI-206 alarms on low differential pressure	
2.12	High interface	NCC			
2.13	Low interface	NCC			

Table 19-2

(Page 4 of 16)

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
2.0 Heater - Circulation Bed Combustor (Drawing: D-20-11-002) (Continued)					
2.14	High concentration of contaminants	High level of acid gas	Refractory damage	Limestone addition to neutralize acid gases	016 017
		Failure of limestone feed	Damage to gas cleaning system		
		High salt level in feed	Slagging potential		
			High salt levels		
3.0 Line - Fuel to CBC (Drawing: D-20-11-001)					
3.1	High flow	Failure of TIC 206 low	High temperature in the combustor; possible refractory damage	TI-209 alarms high	
		Failure of FIC 219 to high output	Potential release of fuel gas	Block valves YV-219A and C interlocked to close if YV-219B opens	
		Failure of FE-219 low			
		YV-219B fails open			
3.2	Low/now flow	PCV-209 regulator fails	Low combustion temperature with incomplete combination	TSLL-206 alarm low	
		FV-219 fails closed		ASHH-502 alarms high CO	
		YV-219A or B fail closed			
		TIC-206 fails high			
		FIC-219 fails low			
		TY-206 fails high			
3.3	Reverse/misdirected flow	NCC			
3.4	High temperature		No significant consequences (NSC)		
3.5	Low temperature	Freezing temperature	Potential condensation; poor combustion	AI-502 alarms high	018
3.6	High pressure	High pressure from source	Poor combustion	PSHH-209 alarms high	
		PCV-209 fails to regulate pressure		FV-219 adjusts flow	

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
3.0 Line - Fuel to CBC (Drawing: D-20-11-001) (Continued)					
3.7	Low pressure	PCV-209 regulator malfunctions Low source pressure	Poor combustion	PSL-209 alarms low PSLL-209 alarms low low FV-219 adjusts flow	
3.8	High concentration of contaminants	Excess contaminants in fuel source	Blocked flow; poor combustion	None	019
3.9	Leak	Corrosion Crack in lie Loose fittings	Release of gas to atmosphere High fuel consumption	None	020
3.10	Rupture	Impact line by heavy equipment	Large release to atmosphere Potential for explosion	None	
4.0 Line - Fuel to Burner (Drawing: D-20-11-001)					
4.1	High flow	Failure of FE-209 low Failure of TIC 207 low Failure of FIC 209 to high output	High temperature in the combustor; possible refractory damage	TI-209 alarms high PSHH-209 alarms high	
4.2	Low/no flow	FIC-209 fails low PCV-209 regulator fails FV-209 fails closed YV-209A or B fail closed TIC-207 fails high TY-207 fails high	Low combustion temperature with incomplete combination	TSLL-207 registers temperature; alarms low ASHH-502 alarms high	
4.3	Reverse/misdirected flow	NCC			
4.4	High temperature	See 3.4			

Table 19-2

(Page 6 of 16)

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
4.0 Line - Fuel to Burner (Drawing: D-20-11-001) (Continued)					
4.5	Low temperature	See 3.5			
4.6	High pressure	High pressure from source PCV-209 fails to regulate pressure	Poor combustion	PSHH-209 alarms high	
4.7	Low pressure	PCV-209 regulator malfunctions Low source pressure	Poor combustion	PSL-209 alarms low PSLL-209 alarms low low	
4.8	High concentration of contaminants	See 3.8			
4.9	See 3.9				
4.10	Rupture	See 3.10			
5.0 Line - Primary Combustion Air (Drawing: D-20-11-001)					
5.1	High flow	FIT-209 high output FFIC-204 fails to properly ratio flow FE-204 fails low FIT-204 low output	Decreased temperature during start-up Incomplete combustion	TSLL-207 alarms low temperature	
5.2	Low/no flow	FIT-209 low output FFIC-204 fails to properly ratio flow FE-204 fails high FE-204 fails closed B-2001 fails PV-201 fails open	Increased temperature during start-up Incomplete combustion Flameout	TSHH-207 alarms high temperature FSLL-204 alarms low flow FSLLL-204 alarms low low flow PSLL-204 alarms low pressure BE-204 alarms on loss of flame	
5.3	Reverse/misdirected flow	NCC			
5.4	High temperature	See 5.2			
5.5	Low temperature	See 5.1			

Table 19-2

(Page 7 of 16)

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
5.0 Line - Primary Combustion Air (Drawing: D-20-11-001) (Continued)					
5.6	High pressure	PIC-201 fails low PV-201 fails closed FFIC fails to ratio flow FE-204 fails low	Poor combustion	AI-502 alarms high; PV-201 opens	
5.7	Low pressure	PIC-201 fails high FFIC fails to ratio flow FE-204 fails high FV-204 fails closed PV-201 fails open	Poor combustion Temperature decrease Flameout	AI-502 alarms high PSLL-204 alarms low TSLL-207 alarms low BE-209 alarms on loss of flame	
5.8	High concentration of contaminants	Inlet valve filter fails	Erosion of line	None	021
5.9	Leak	Loose fitting downstream of flow meter	Poor combustion Increased temperature	TSHH-207 alarms high AI-502 alarms on high CO	
5.10	Rupture	See 1.10			
6.0 Line - Secondary Combustion Air (Drawing: D-20-11-001)					
6.1	High flow	FIC-201 fails low FY-201 fails low TIC-206 fails high PV-201 fails closed PIC-201 fails low FV-201 fails open FIT-501 fails low	Low temperature Poor combustion High particulate carry over	TSLL-207 alarms high TE-206 and 209 alarm high AI-502 alarms high PIC-201 controls pressure	022

Table 19-2

(Page 8 of 16)

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
6.0 Line - Secondary Combustion Air (Drawing: D-20-11-001) (Continued)					
6.2	Low/now flow	FIC-201 high output PV-201 fails open B-2001 fails PIC-201 fails high FIT-501 fails high TIC-206 fails high or low?	Poor combustion Increased temperature Loss of bed fluidization	FSLL-201 alarms low TSHH-207 alarms high AI-502 alarms high	023
6.3	Reverse/misdirected flow	NCC			
6.4	High temperature	See 6.2			
6.5	Low temperature	See 5.1			
6.6	High pressure	See 6.1			
6.7	Low pressure	See 6.2			
6.8	High concentration of contaminants	See 5.8			
6.9	Leak	See 5.9			
6.10	Rupture	See 5.10			
7.0 Line - Ash to Ash Bin (Drawing: D-20-11-002)					
7.1	High flow	High speed in H-2001	Overheat conveyor Empty CBC of solids Overheat conveyor drive motor	PDI-206 alarms low TI-210 alarms on high temperature ISHH-208 alarms on high motor current	024
7.2	Low/no flow	Plugging of chute Failure of H-2001 speed control or motor Excessive vacuum in CBC	Fill CBC with solids Prevent bed fluidization	ISHH-208 alarms on high motor current HL-208A indicates motor status	

Table 19-2

(Page 9 of 16)

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
7.0 Line - Ash to Ash Bin (Drawing: D-20-11-002) (Continued)					
7.3	Reverse/misdirected flow	NCC			
7.4	High temperature	Failure of P-2001 Closed block valve Failure of cooling water supply	Damage to ash cooler conveyor system	None	025
7.5	Low temperature	Freezing temperature	NSC		
7.6	High pressure	NCC			
7.7	Low pressure		NSC		
7.8	High concentration of contaminants	Incomplete combustion of solids	Potential explosive or toxic contaminants	Testing of ash quality	026
7.9	Leak	Erosive or corrosive action on conveyor housing	Spill of contaminated materials	None	027
7.10	Rupture	NCC			
8.0 Line - Off-Gas to Partial Quench (Drawing: D-20-11-002)					
8.1	High flow	See 2.1	NSC		
8.2	Low/now flow		NSC		
8.3	Reverse/misdirected flow	NCC			
8.4	High temperature		NSC		
8.5	Low temperature		NSC		
8.6	High pressure		NSC		
8.7	Low pressure		NSC		
8.8	High concentration of contaminants		NSC		

Table 19-2

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
8.0 Line - Off-Gas to Partial Quench (Drawing: D-20-11-002) (Continued)					
8.9	Leak	Erosion or corrosion of pipeline	Infiltration of air	None	See 014
8.10	Rupture	NCC			
9.0 Line - Process Water (Drawing: D-50-11-001)					
9.1	High flow	TV-501 fails open TIT-501 or TIC-501 fails high	Water in T-5002A Plugging of baghouse Low quenched gas temperature Corrosion of downstream equipment	None	028 029 030
9.2	Low/no flow	TV-501 fails closed TIT-501 fails low Supply pump failure	Temperature in T-5001 too high; potential damage to vessel	TSHH-501 alarms high FSL-501 alarms low Emergency water supply available	
9.3	Reverse/misdirected flow	NCC			
9.4	High temperature	See 9.2			
9.5	Low temperature	Freezing temperature	Potential freeze of emergency water line	None	031
9.6	High pressure	NCC			
9.7	Low pressure	TV-501 fails closed Source feed pump fails	See 9.2	See 9.2	
9.8	High concentration of contaminants	NCC			
9.9	Leak		See 9.2		
9.10	Rupture	High stress in pipe due to outside force	Loss of cooling water	Emergency water supply	

Table 19-2

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
10.0 Line - Plant Air (Drawing: D-50-11-001)					
10.1	High flow		NSC		
10.2	Low/now flow	Plant air compressor fails PCV-502 fails closed	Loss of cooling spray jet; high temperatures	FSL-502 alarms low flow Emergency water system TAHH-501 alarms on high temperature	
10.3	Reverse/misdirected flow	NCC			
10.4	High temperature	NCC			
10.5	Low temperature		NSC		
10.6	High pressure		NSC		
10.7	Low pressure	See 10.2			
10.8	High concentration of contaminants	Failure of plant air filter	NSC		
10.9	Leak		NSC		
10.10	Rupture	NCC			
11.0 Vessel - Partial Quench (Drawing: D-50-11-001)					
11.1	High level	NCC			
11.2	Low level		NSC		
11.3	High interface	NCC			
11.4	Low interface	NCC			
11.5	High temperature	See 9.2			
11.6	Low temperature	See 9.1	See 9.1		
11.7	High pressure	Loss of ID Fan Pluggage of baghouse	Possible leakage of off-gas	PDSH-504 alarms high ID fan loss results in system shutdown	

Table 19-2

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
11.0 Vessel - Partial Quench (Drawing: D-50-11-001) (Continued)					
11.8	Low pressure		NBC		
11.9	High concentration of contaminants	High level of acid gas High salt levels	Damage to vessel interior Pluggage of H-5001	Limestone addition to CBC	032
11.10	Leak	Lack of seal at vessel inflow and outflow points	Release of gas to atmosphere	None	See 014
11.11	Rupture	NCC			
12.0 Line - Compressed Air (Drawing: D-50-11-001)					
12.1	High flow		NSC		
12.2	Low/no flow	Loss of plant air compressor PCV-508 fails closed	Baghouse system failure	PDSL-504 alarms high	
12.3	Reverse/misdirected flow	NCC			
12.4	High temperature		NSC		
12.5	Low temperature		NSC		
12.6	High pressure	PCV-508 fails to regulate pressure PCV-507 fails to regulate pressure	Excessive wear on bags; possible leakage from bags	None	033
12.7	Low pressure	Inadequate plant air supply pressure	See 12.2		
12.8	High concentration of contaminants	Inadequate filtration of plant air supply High moisture level in air supply	Baghouse system failure due to moisture sealing bags	None	034
12.9	Leak		NSC		
12.10	Rupture	NCC			

Table 19-2

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
13.0 Line - Baghouse (Drawing: D-50-11-001)					
13.1	High flow	See 2.1	Reduced particulate removal	PDAH-504 alarms high	
13.2	Low/now flow	See 2.2	NSC		
13.3	Reverse/misdirected flow	NCC			
13.4	High temperature	See 2.4	Potential for ignition of bags	TE-502 and TAHH-501 alarm on high temperature	035
13.5	Low temperature	Excessive water in T-5001	Plugging bag house	TAL-503 alarms low	
13.6	High pressure	Bags become laden with dust; cleaning system ineffective	Higher system drop; excessive load on ID fan	PDSH-504 alarms on high pressure drop	
13.7	Low pressure	Tear in bag filters	Inefficient cleaning or lack of gas cleaning	PDSL-504 alarms on low pressure drop	
13.8	High concentration of contaminants	Excessive carryover from CBC	Baghouse overloaded	PDSH-504 alarms on high pressure drop	
13.9	Leak	See 1.9			
13.10	Rupture	NCC			
14.0 Line - Baghouse Discharge (Drawing: D-50-11-001)					
14.1	High flow		NSC		
14.2	Low/no flow	Plugged cone	Shutdown for cleaning; loss of utilization	Vibrator on cone	
14.3	Reverse/misdirected flow	NCC			
14.4	High temperature	See 13.4			
14.5	Low temperature	See 13.5	See 13.5		
14.6	High pressure	NCC			
14.7	Low pressure	NCC			
14.8	High concentration of contaminants	Inefficient or incomplete combustion	Recycle contents through the CBC; reduced utilization	See 2.6	

Table 19-2

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
14.0 Line - Baghouse Discharge (Drawing: D-50-11-001) (Continued)					
14.9	Leak	NCC			
14.10	Rupture	NCC			
15.0 Line - Stack (Drawing: D-50-11-001)					
15.1	High flow	See 2.1 and 6.1 FIT-503 fails low FE-503 fails PV-501 fails open	Reduced treatment effectiveness	FAHH-503 alarms high FIC-201 indicates flow	036
15.2	Low/no flow	See 2.2 and 6.2 ID fan fails PV-501 fails closed	Low system throughput	FIC-201 indicates flow	037
15.3	Reverse/misdirected flow	NCC			
15.4	High temperature	See 11.5			
15.5	Low temperature	See 11.6			
15.6	High pressure	PV-501 fails open B-5001 high output PIC-210 fails low	Stack flow will increase resulting in lower secondary air and loss of bed fluidization	FSHH-503 alarms high ASLL-501 alarm on low oxygen	
15.7	Low pressure	PV-501 fails closed B-5001 fails or low output PIC-210 fails high	Stack flow will decrease resulting in higher secondary air and increased carryover of particulate	Failure of ID fan will shut down system	

Table 19-2

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
15.0 Line - Stack (Drawing: D-50-11-001) (Continued)					
15.8	High concentration of contaminants	Breakthrough in baghouse High acid gas levels	Exceed emission limits	PDSL-504 alarms low differential pressure	038
15.9	Leak		NSC		
15.10	Rupture	NCC			
16.0 Line - CBC Purge Air (Drawing: D-201-11-002)					
16.1	High flow	High flow due to failure of damper valve	High flow in CBC; potential excessive carryover of particulate	PDI-206 alarms on high pressure drop	
16.2	Low/now flow	B-2002 fails Damper valve fails closed	Bed fluidization not maintained	PDI-206 alarms on low pressure differential	
16.3	Reverse/misdirected flow	NCC			
16.4	High temperature		NSC		
16.5	Low temperature		NSC		
16.6	High pressure	See 16.1			
16.7	Low pressure	See 16.2			
16.8	High concentration of contaminants		NSC		
16.9	Leak		NSC		
16.10	Rupture	NCC			
17.0 Line - Limestone Feed (Drawing: D-20-11-002)					
17.1	High flow	High H-2002 motor speed	Fills CBC with limestone	None	039
17.2	Low/no flow	Motor fails Plugged inlet Feed material not available	Decreased neutralization of aid gases	HL-201A indicates motor run status	040

Table 19-2

(Page 16 of 16)

Item Number	Deviation	Causes	Consequences	Safeguards	Actions
17.0 Line - Limestone Feed (Drawing: D-20-11-002) (Continued)					
17.3	Reverse/misdirected flow	NCC			
17.4	High temperature		NSC		
17.5	Low temperature		NSC		
17.6	High pressure	NCC			
17.7	Low pressure	NCC			
17.8	High concentration of contaminants		NSC		
17.9	Leak		NSC		
17.10	Rupture	NCC			
18.0 Line - Ash Cooler Conveyor (Drawing: D-20-11-002)					
18.1	High flow	See 7.1			
18.2	Low/no flow	See 7.2			
18.3	Reverse/misdirected flow	See 7.3			
18.4	High temperature	See 7.4			
18.5	Low temperature	See 7.5			
18.6	High pressure	See 7.6			
18.7	Low pressure	See 7.7			
18.8	High concentration of contaminants	See 7.8			
18.9	Leak	See 7.9			
18.10	Rupture	See 7.10			

recommendations, and human error and natural occurrences each accounted for two recommendations.

The action items are to be reviewed by IT engineers and USAEC personnel to determine what changes in the design and operating procedures (if any) are required to satisfy the concerns or recommendations. The results of this study are incomplete until all of the 40 recommendations have been addressed. Twenty of the recommendations are designated to be resolved by IT engineers and 20 are the joint responsibility of IT and USAEC personnel. To complete the HAZOP, all resulting decisions are to be entered in the status column of the action report. Because the project design is at a conceptual stage, completion of all action items will be deferred later in the project in the process design or detailed design stages.